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th Annual Report
# of the
New York State Museum
and Science Service

July 1, 1963 - June 30, 1964

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NEW YORK STATE MUSEUM AND SCIENCE SERVICE

The University of the State of New York
The State Education Department

ALBANY, NEW YORK 1965

126th Annual Report of the New York State Museum and Science Service

The University of the State of New York

The State Education Department

1784

ALBANY, NEW YORK

1965

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The University of the State of New York

Regents of the University	*Years when terms expire*
EDGAR W. COUPER, A.B., LL.D., L.H.D., *Chancellor*, Binghamton	1968
THAD L. COLLUM, C.E., *Vice-Chancellor*, Syracuse	1967
ALEXANDER J. ALLAN, JR., LL.D., LITT.D., Troy	1978
GEORGE L. HUBBELL, JR., A.B., LL.B., LL.D., LITT.D., Garden City	1966
CHARLES W. MILLARD, JR., A.B., LL.D., Buffalo	1973
EVERETT J. PENNY, B.C.S., D.C.S., White Plains	1970
CARL H. PFORZHEIMER, JR., A.B., M.B.A., D.C.S., Purchase	1972
EDWARD M. M. WARBURG, B.S., L.H.D., New York	1975
J. CARLTON CORWITH, B.S., Water Mill	1971
JOSEPH W. MCGOVERN, A.B., LL.D., L.H.D., LL.D., New York	1969
ALLEN D. MARSHALL, A.B., LL.D., Scotia	1965
JOSEPH T. KING, A.B., LL.B., Queens	1977
JOSEPH C. INDELICATO, M.D., Brooklyn	1974
MRS. HELEN B. POWER, A.B., LITT.D., Rochester	1976

JAMES E. ALLEN, JR.	President of the University and Commissioner of Education
EWALD B. NYQUIST	Deputy Commissioner of Education
HUGH M. FLICK	Associate Commissioner for Cultural Education
WILLIAM N. FENTON	Assistant Commissioner for State Museum and Science Service
VICTOR H. CAHALANE	Assistant Director of State Museum

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155

Contents

iv MUSEUM ADVISORY COUNCIL

v THE STAFF

1 GENERAL STATEMENT

8 ACCOMPLISHMENTS OF THE SURVEYS

8 Anthropological Survey

10 Biological Survey

12 Geological Survey

16 THE MUSEUM

27 APPENDICES

35 PUBLICATIONS

Museum Advisory Council

1964	Frederick J. Dockstader,	New York City
1965	William C. Steere,	New York City
1966	George F. Goodyear,	Buffalo
1967	Chester M. Suter,	Chatham
1968	Brian H. Mason,	New York City

The Staff

State Museum and Science Service

WILLIAM N. FENTON	Assistant Commissioner

Anthropological Survey

WILLIAM A. RITCHIE	State Archeologist, Associate Scientist
ROBERT E. FUNK	Junior Scientist

Biological Survey

DONALD L. COLLINS	State Entomologist, Principal Scientist
DONALD P. CONNOLA	Senior Scientist (Entomology)
PAUL F. CONNOR	Scientist (Zoology)
RODNEY C. DE GROOT	Senior Scientist (Botany)
HUGO A. JAMNBACK, JR.	Senior Scientist (Entomology)
DONALD M. LEWIS	Junior Scientist
EUGENE C. OGDEN	State Botanist, Associate Scientist
RALPH S. PALMER	State Zoologist, Associate Scientist

Geological Survey

JOHN G. BROUGHTON	State Geologist, Principal Scientist
JAMES F. DAVIS	Scientist (Geology)
DONALD W. FISHER	State Paleontologist, Associate Scientist
Y. WILLIAM ISACHSEN	Associate Scientist (Geology)
W. LYNN KREIDLER	Senior Scientist (Geology)
LAWRENCE V. RICKARD	Senior Scientist (Paleontology)
ROSS P. SANGSTER	Science Research Aide — Wellsville Office
ARTHUR M. VAN TYNE	Scientist (Geology) — Wellsville Office
VACANT	Senior Scientist (Geochemistry)

State Museum

VICTOR H. CAHALANE	Assistant Director

Curatorial

ROGER L. BORST	Associate Curator (Geology)
JENNIFER CHATFIELD	Associate Curator (Interpretation)
CHARLES E. GILLETTE	Associate Curator (Archeology)
CLINTON F. KILFOYLE	Associate Curator (Paleontology)
EDGAR M. REILLY, JR.	Associate Curator (Zoology)
STANLEY J. SMITH	Associate Curator (Botany)
JOHN A. WILCOX	Associate Curator (Entomology)

Exhibits

HELEN C. FISHER	Museum Technician (NDEA)
EDITH FROELICH	Museum Technician (Temporary)
LEWIS E. KOHLER	Museum Technician
LOUIS J. KOSTER	Senior Museum Technician
HAROLD W. ROSS	Museum Technician (NDEA)
ROBIN D. ROTHMAN	Museum Technician
THEODORE P. WEYHE	Museum Exhibits Designer

School Services

C. MICHAEL DARCY	Museum Education Supervisor
S. CRAIG SMITH	Museum Instructor (NDEA)
MARY JANE STAUCH	Museum Instructor (Temporary)
PAUL WEINMAN	Museum Instructor

Library

EILEEN COULSTON	Librarian, Junior Scientist

Clerical

MARION B. BENDER	Clerk
MARYELLEN CANFORA	Stenographer
LINDA A. HEERAN	Stenographer (NDEA)
JOAN C. KELLEY	Senior Stenographer
JOSEPH T. KILLEA	Mail and Supply Helper
ROSELLE LITHGOW	Clerk
PATRICIA SARGOOD	Stenographer
MARJORIE R. SCHMIDT	Principal Clerk
GRACE SMITH	Senior Stenographer
CATHERINE M. STAPLETON	Stenographer
MARY C. STEARNS	Stenographer
EILEEN A. WOOD	Senior Stenographer

Guards

JOHN C. CUNNINGHAM	Building Guard
ANTHONY GENSICKI	Building Guard
EDWARD W. MCCARTY	Building Guard
WILLIAM C. ZIMMER	Museum Caretaker

Photographer

JOHN A. HELLER	Museum Photographer

Maintenance

JACOB SMALLENBROEK	Carpenter
JAMES WIEDEMANN	Maintenance Man (Carpenter)

General Statement

I have the honor to return a report on the activities and accomplishments of the New York State Museum and Science Service for the year ended June 30, 1964.

The leveling of buildings between State Street and Lincoln Park for the South Mall has enhanced the prospect for a new State Museum building. The planning effort for a new museum facility occupied the major attention of the staff during much of the year. Although the cultural center may not occupy a very high priority in the minds of State budgeters and planners, it is apparent that something will have to be done to relieve the dreary monotony of office buildings. No tourist is going to come to Albany to see State offices, but he will come to visit a cultural center. As the director of a great natural history museum remarked, "If they've torn down the buildings, you've got it made."

This concern is shared by the planners. At the end of the calendar year 1963, the officers of the Department were called to a conference in the Office of General Services, and almost overnight we were required to file requirements for museum galleries, the storage of collections, and laboratories for the scientists of the Science Service. Anticipating that this demand would arise, we had sketched the dimensions of this facility and the nature of its programs in the *124th Annual Report of the New York State Museum and Science Service,* which happily we were able to put on the table at the first planning meeting. Copies were also in the hands of the budget examiners.

With full knowledge that improved public relations would be necessary to sell such a facility to the taxpayer who will pay for it and use it, to put our colleagues in the museum profession throughout the nation on notice, and to fulfill the request of the American Association of Museums, we commissioned the writing of a general sketch of our services to the public entitled "A Service to Science" which appeared in the January issue of *Museum News.* Reprints of the article documented a presentation to the Regents which was attended by the Commissioner of General Services on January 23. The requirements for the new facility which were then in preparation were filed February 3.

The most difficult to communicate and yet the most significant requirement of any such facility is the need for a balance of space between exhibit galleries, ranges for systematic collections, laboratories, and other facilities. A proportion of 40-40-20 is a standard rule in the museum profession that is most honored in the breach by architects. One of the most serious difficulties in communicating this idea to architects is the length of the chain of command and the possibility of the erosion or rearrangement of the balance so that the galleries completely dominate the museum to conform with the popular image. We have had the good fortune of a personal visit from the chief architect for the Mall; if we can now arrange to develop a close working relationship with his firm by affording one of his junior architects working space within our establishment, it is conceivable that our program requirements can be translated into architects' plans.

In viewing museum buildings around the world, we have seen altogether too many examples of the erosion of the original formula in government-built museums. In one instance, no offices were provided for the staff, to say nothing of storage for collections. In another, laboratories were omitted. In a third museum, air conditioning compressors completely filled a hall, and in a fourth instance, no one anticipated the depth of ceiling required for recessing air conditioning ducts and lighting for museum galleries. With these matters in mind, the Assistant Commissioner attended the dedication of the new Museum of History and Technology of the Smithsonian Institution and inspected the new research facilities and ranges of the U. S. National Museum of Natural History. The Assistant Director continued his close contacts with other museum facilities under construction. To this end, he and the Associate Commissioner visited the Milwaukee Public Museum and museums in Chicago, as did the Assistant Commissioner on another occasion.

Cooperation with other museums of the State has increased markedly during the year. The "museum aid bill" as the legislation implementing the so-called "Hochschild Report," as the *Report of the Commissioner's Committee on Museum Resources* has come to be known, was introduced a second time in the 1964 Legislature, without success. Both the report and the legislation have aroused wide interest in the nation, stimulating inquiries from New Jersey, Illinois, Connecticut and California, but the legislation has not yet attracted sufficient grass roots support within New York State to secure its passage. To be certain, the New York State Association of Museums has skillfully guided the legislation and made its existence known to legislative leaders who have expressed sympathy for it, and strong support has come from the major cultural institutions of New York

City, Rochester and Buffalo. So far, the bill has fallen between the two stools of massive appropriations for the Education Department and insufficient revenues. It is apparent that State aid for museums is undergoing the same life cycle as State aid to libraries, and that ultimately it will be an accepted part of the State Education Department's package of services to cultural institutions.

A related phase of cooperation with other museums is an increase in the number of queries for the chartering of new museums. The staff assisted several new corporations in the formation of museums. The Assistant Commissioner, at the request of an attorney, visited the extensive collection of a private citizen in Rochester with a view to recommending a way to convert a private collection to educational purposes. He also visited several institutions that had been chartered in previous years to render further advice on their programs. It is apparent that, as the demand for this service increases, a museum extension division is in the offing. Looking forward from chartering museums to their registration under the State aid bill, the Regents Minutes and other records of the Department were researched toward compiling an up-to-date list of museums that might qualify as educational institutions.

Saying "no" to a taxpayer is sometimes difficult. Gracefully refusing to hang in the Museum a framed photograph of a natural formation (operated as an attraction for private gain) because accepting the gift would imply in the donor's mind the obligation of the State Museum to exhibit it and would therefore give one commercial enterprise an unfair advantage over others is an awkward situation that skates the narrow line between a geologic or archeologic site and private enterprise. It is much easier to give advice to the trustees of a nature preserve, or even to a commercial bank concerning natural history prints appropriate as decor for bank offices, or to an arboretum as a possible research site for our scientists. Simplest of all is to give advice in one's specialty, as to assist a composer in his search for Seneca music. Perhaps most satisfactory was the continuing advisory capacity of the Assistant Commissioner to the Seneca Nation of Indians toward planning their rehabilitation as a result of the building of the Kinzua Dam.

Cooperation at the professional level is one of the most enjoyable and rewarding experiences for the scientist-administrator. SIAM are the initials for the Summer Institute in Anthropology for Museums which was held in July and August at the University of Arizona, Tucson, and involved three members of our staff. SIAM was a six weeks' training course for museum personnel, sponsored by the American Association of Museums, financed by the National Science Foundation, and held at the Arizona State Museum. It was one of two such training programs to upgrade the quality of teaching in the two most popular natural science areas of museum interpretation—anthropology and astronomy. Fellowships were awarded to two members of our staff—the Associate Curator of Archeology and a Museum Instructor—and the Assistant Commissioner, who was a member of the planning committee, participated for one week as a consultant teacher. Participants felt it was a valuable experience. It was probably the best-staffed summer course in anthropology held in any university in recent years. For some of us, the return to teaching was a welcome experience.

At the research level, we were involved in the organization and conduct of a conference on anthropological research in museums held at the National Museum of Canada, Ottawa, during October. Here, an attempt was made to explore the ways that anthropological collections in museums can be used most fruitfully to advance research in the study of man and how museums may best get back into the forefront of anthropology as a science.

The scientist-administrator who does not maintain some contact with the field or the laboratory dies on the vine as the field is converted to other uses. In response to a request from the Conservation Department for an article on the Seneca Green Corn Ceremony, the writer spent a week in the field during July with the Seneca Indians of Allegany Reservation, the site of his former research, and then a week writing the article. He also edited for publication Captain William Hyde's *Observations on the Five Nations of New Yorke, 1698,* the first description of these interesting people by an English observer. The original manuscript is in the Gilcrease Foundation, Tulsa, Oklahoma, and was discovered by the writer some years ago. He also continued the writing of a general book on the Five Nations of New York (which was commenced during a Professional Development Leave).

A research administrator takes greatest pride in research accomplished by his staff. He is also proud of their ability to attract grants from outside sources. Just as the universities have experienced an alteration of their structure as a result of private and public grants that have come to the faculty, so a public museum that has been wholly supported by public funds finds it difficult to ingest grants secured by its staff scientists. We now have two large public grants from national foundations and two smaller private grants from private foundations, which in total exceed the annual Science Service

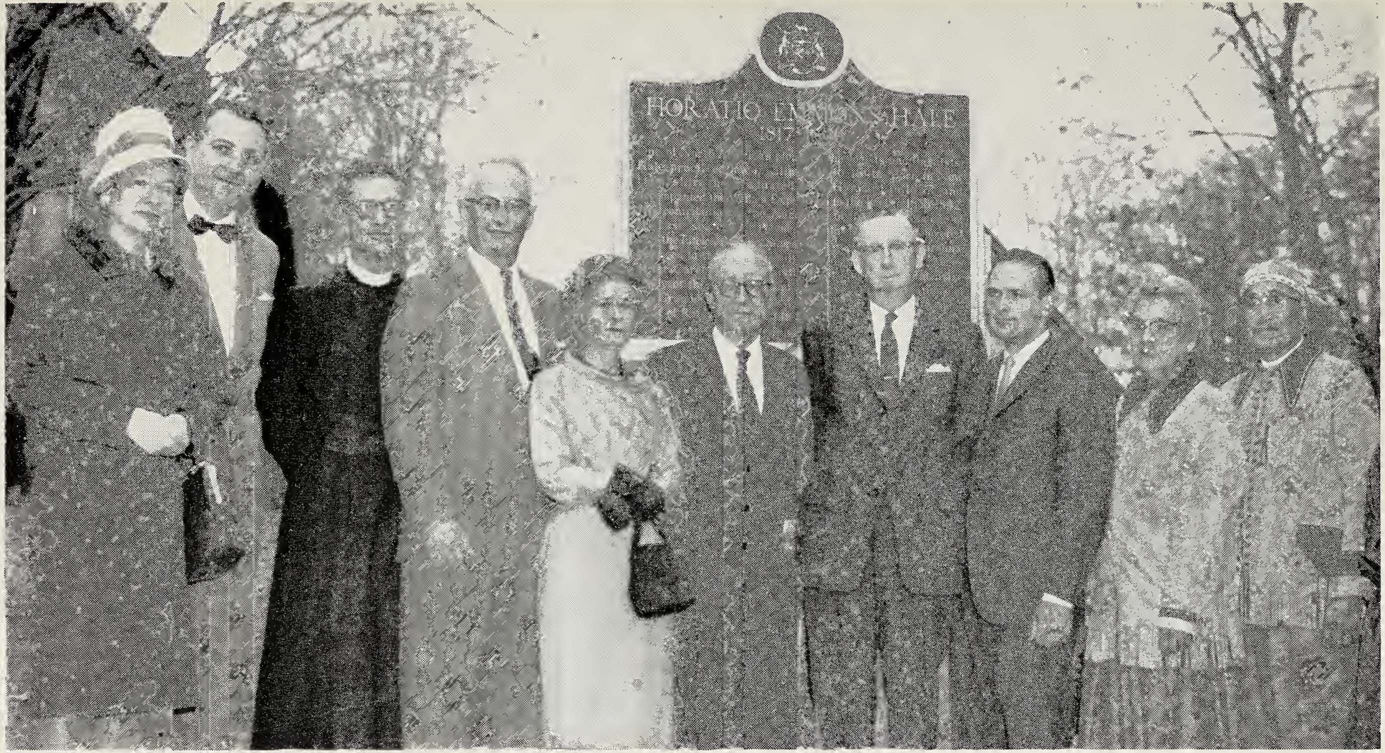

Figure 1. On October 19, 1963, the province of Ontario, the village of Clinton, the Six Nations, the New York State Museum and Science Service, and the University of Toronto Press honored Horatio Emmons Hale (1817-1896), the eminent Iroquoian scholar, on the occasion of the reprinting of his classic *The Iroquois Book of Rites,* for which Dr. William N. Fenton wrote the introduction. (Ontario Dept. of Travel and Publicity photo)

research budget. The principal investigator who receives his salary and travel from the public institution finds himself in a conflict of reporting relationships between his administrative superiors and the granting agency. There is a tendency to take one's public position for granted and look to one's colleagues in the community of science for judgment on one's research results. The scientist naturally looks upon his research grant as his project, and does not always regard it in the same way he does State-financed research. Even though the grants come from public funds or from funds given in lieu of taxes, and are made to a public institution, reporting relationships become confused.

A second aspect of national grants to State and private universities affects the acquisition of new collections. Within the last year, while the State Museum was awaiting the disposition of a budget request for the purchase of a fossil collection within the State, which would have been an important research adjunct to the State's large collection of invertebrate fossils, the same collection was purchased by an out-of-State university, and a State university at that, with funds furnished to a principal investigator by the National Science Foundation. Had the New York State Museum applied to the National Science Foundation for funds to purchase the collection, which we would deem an inappropriate request, it probably would have been denied.

As a professional anthropologist, the writer served as an officer of one learned society, honored the usual requests of colleagues to address their students, served on a fellowship screening committee, and was involved in three trips to Canada on literary, museum, and university matters, all at the request of Canadian officials, as listed in the Appendices. His office was deeply involved in the preliminary stages of American participation in the International Congress of Anthropological and Ethnological Sciences which involved communication with a wide variety of agencies. Of possible interest to educators, he wrote one of the chapters for the *Report of the Commission on the Humanities.*

It is frequently said of the State Museum that "when European men of science come to this country, their first question is, 'Which way is Albany?'" The famous words were spoken by Louis Agassiz, the Swiss naturalist of the last century, in addressing the American Association for the Advancement of Science at Albany, 1856. It might be said that this question is still asked.

Visitors of the year included Godfried W. Locher, Professor of Anthropology, University of Leiden, Holland; Rudolph Karl Bigalke, MacGregor Museum, Kimberley, South Africa; and Frem Pong Bdu, Nigeria, graduate fellow at Yale.

STAFF CHANGES

On September 5, C. Michael Darcy was appointed provisionally to the position of Museum Education Supervisor vacated July 25 by Janet L. Stone, who began a two year leave of absence with the Peace Corps in Africa. Judith A. Drumm resigned September 4 to undertake graduate study at Rutgers University, and Paul Weinman was appointed to this instructorship on December 12. Maryellen Canfora's position of Typist was reclassified to Stenographer on July 25. On October 17, S. Craig Smith was appointed to the Museum Instructor position vacated by Mr. Darcy and Grace Smith was appointed Senior Stenographer upon the resignation of Vera McMillen Wheeler.

William N. Fenton
Assistant Commissioner for
State Museum and Science
Service

Accomplishments of the Surveys

ANTHROPOLOGICAL SURVEY

Aboriginal settlement pattern studies in the Northeast were continued with National Science Foundation support, and new and important facts were obtained. Two field parties headed by the State Archeologist and the Junior Scientist, respectively, with six graduate student assistants carried out intensive excavations on four important prehistoric sites in central and eastern New York and eastern Massachusetts. The work added a large volume of significant settlement pattern information to that already accumulated by our researches under this program into the development of agriculture, village life, and the growth of communal longhouse society.

At Kipp Island in central New York the first settlement pattern data for the Point Peninsula culture of the Middle Woodland period were uncovered. Three types of houses were revealed, together with a large amount of artifact materials and hearth charcoal from which radiocarbon dates ranging between A.D. 310 and 630 have been secured. A cemetery connected with this site was also explored, yielding the remains of 120 individuals and significant burial data.

At Vineyard Haven, Massachusetts, the State Archeologist excavated a stratified site of the Early Woodland period and obtained abundant data relating to the cultural sequence and to the adaptation of a primitive group to a coastal ecology.

Two large village sites of the Late Woodland period, Kelso in central New York and Garoga in the eastern part of the State, were excavated under the supervision of the Junior Scientist. The former site, representing the earliest Iroquois village so far known, was characterized by two large palisaded enclosures and numerous protolonghouses ranging up to 128 feet in length. The Garoga village of the late prehistoric Iroquois represents the only complete excavation of a classic Iroquois town site on record.

In addition to the above program, work was begun in the Hudson Valley on river valley surveys in New York State for the purpose of discovering the archeological resources of the State and planning for their systematic, long-term investigation.

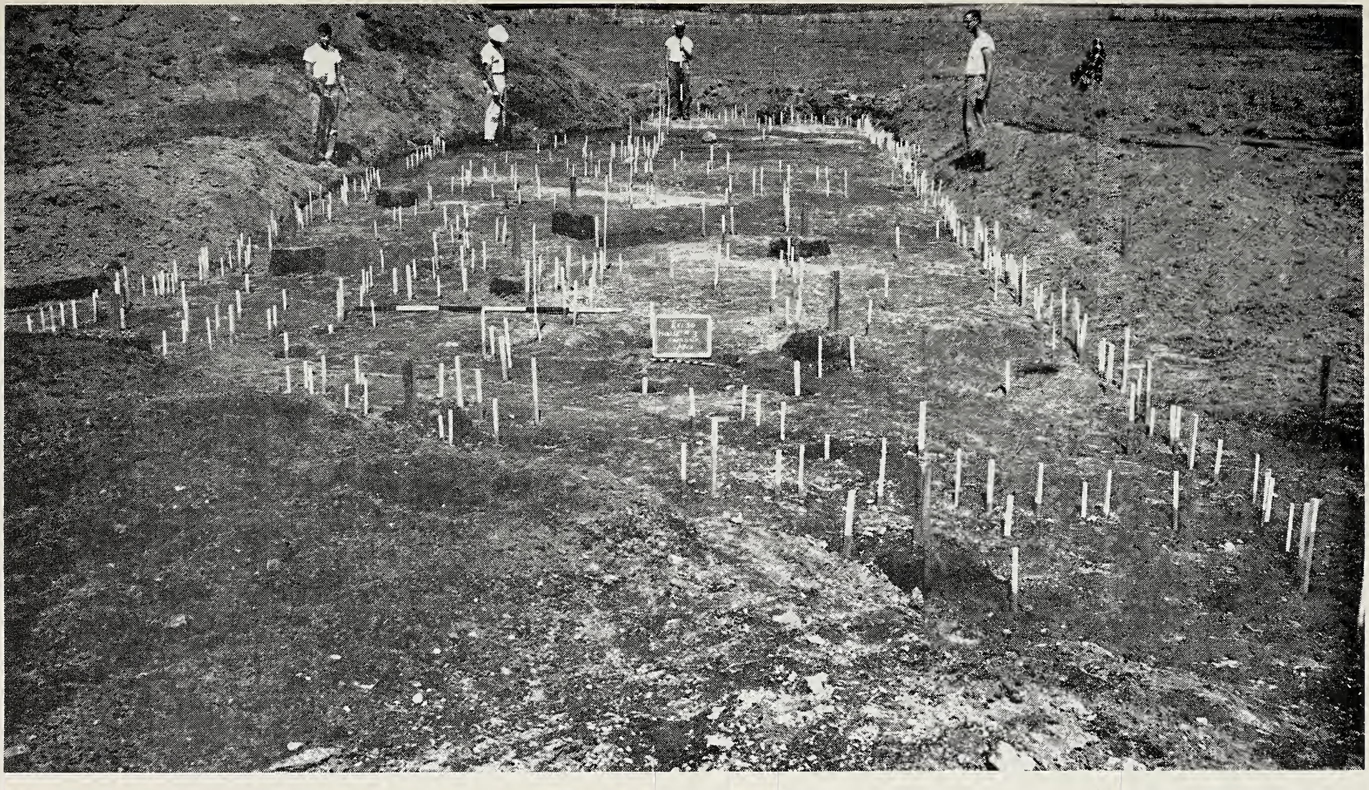

Figure 2. State Science Service personnel excavating floor of ancient longhouse of earliest known Iroquois culture. About one-half is exposed; remainder (foreground) has been backfilled. Kelso site, Elbridge, Onondaga County, N. Y.

During the year the data from the Kipp Island and Kelso site excavations were studied, analyzed, and prepared for publication. The State Archeologist completed a book manuscript entitled *Early Man to Iroquois* to be published by the Natural History Press of the American Museum of Natural History. A paper on "Early Man in New York" was also written; it was read for him at the annual meeting of the American Association for the Advancement of Science in Cleveland.

Cooperative work of the State Archeologist included giving aid, advice, and information to a large number of professional and amateur students, colleagues, State agencies, and others. Finally, office activities and administrative work included interviews with 206 local and out-of-town visitors.

William A. Ritchie
State Archeologist

BIOLOGICAL SURVEY

Most of the work of the Biological Survey is concerned with two large fields: (1) natural resources and ecology and (2) public health. Within these two areas are several programs with separate but interrelated projects.

The first field, natural resources and ecology, includes research on forest pests—fungus diseases, white pine weevil, and gypsy moth; on specialized botany, including studies of fossil pollen and aquatic plants; and on small mammals.

Within the first area, with deterioration of the American beech tree as his first assignment for study, the newly appointed Senior Scientist (Botany) [Mycology] has discovered 20 new fungal associates of beech, and demonstrated a probable connection with the oyster-shell scale insect (*Lepidosaphes ulmi*).

A long-term study in forest ecology and genetics was begun by the Senior Scientist (Entomology). This study will attempt to determine the factors which favor resistance of white pine to attack by white pine weevil. Observations and investigations over a period of several years, some of which were summarized in State Museum and Science Service Bulletin 389 *White Pine Weevil Attack in Relation to Soils and Other Environmental Factors in New York*, by D. P. Connola and Earl C. Wixson, have led to this new approach. It recognizes, incidentally, the desirability of finding methods other than use of chemical insecticides for control of forest and other pests.

The small mammal survey, in addition to its contribution of ecological data and specimens, also has an important bearing on the

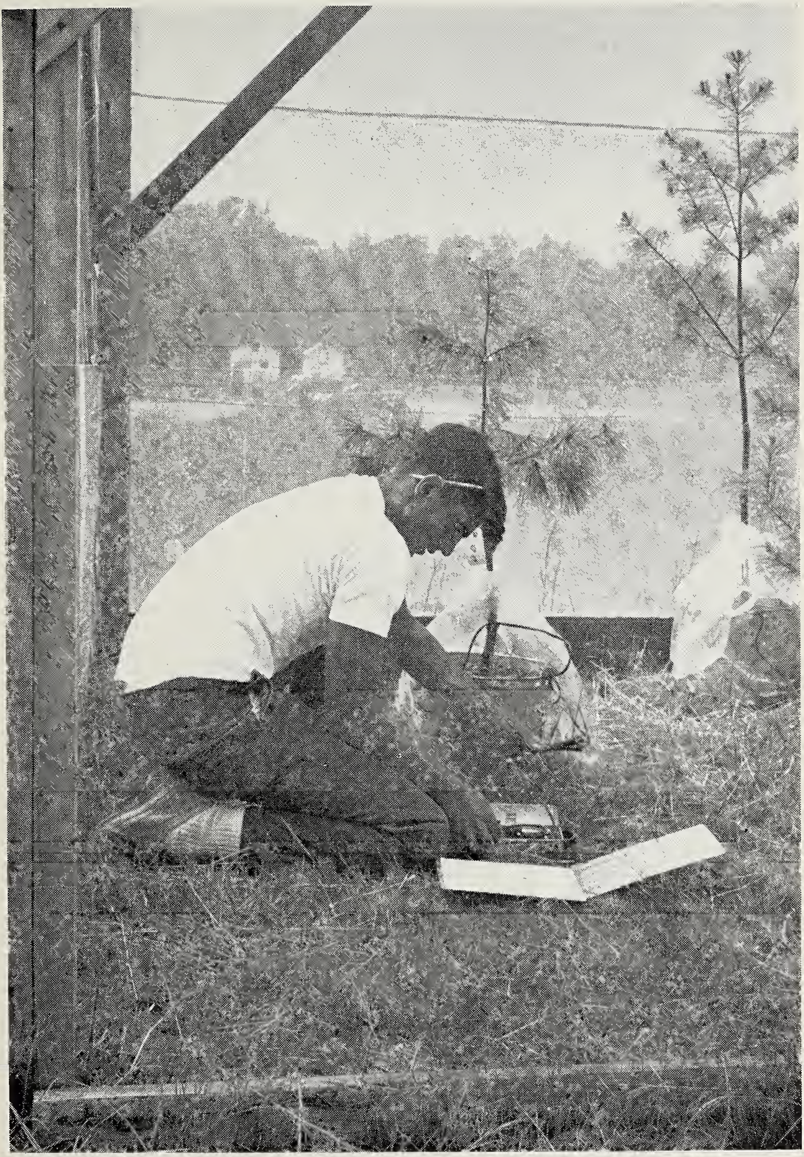

Figure 3. In a study of weevil attack in relation to water balance, white pines were placed in large cages and exposed to the insect. Half of the trees were deprived of moisture by regulating the amounts of water given. Soil moisture was measured (as here) twice weekly by means of a Delmhorst meter.

second or public health area. The Scientist (Zoology) brought specimens of birds, as well as mammals, and his specialized knowledge to the virus, vector, and host survey on Long Island. Of special interest in this program was the finding by Dr. Elinor Whitney, bacteriologist and virologist of the State Health Department, that the six isolates of a new virus from the mosquitoes and animals collected by our staff were related to the Hart Park Virus discovered in California. This new virus was officially named Flanders Virus, from the Flanders Bay area near Riverhead, where the host specimens were found. It was described in a paper by Dr. Whitney in the *American Journal of Tropical Medicine and Hygiene.*

That portion of the pollen studies listed as "Travels of Airborne Pollen" which is supported by a grant from the U. S. Public Health Service is classified in the public health field. The State Botanist, leader of this project, was appointed to the Research Committee of the American Academy of Allergy and was elected chairman of the Committee on Pollen and Mold. A set of instructions for the construction and use of the intermittent rotoslide pollen sampler was prepared, and arrangements were made for distribution of the instructions by the American Academy of Allergy. Detailed blueprints have been made available from the Oak Ridge Reproduction Service in Tennessee.

All members of the Survey have participated in planning for the new Museum and Science Service building that is proposed for the South Mall.

Donald L. Collins
State Entomologist

GEOLOGICAL SURVEY

The Geological Survey is making steady progress in basic and applied research. In order to meet obligations, however, it will be necessary to add specialists in other fields, particularly in environmental geology and its subdivision, urban geology. Data must not only be collected and compiled but they must be prepared in such a way as to be intelligible to laymen and other nongeological specialists.

During the year, the State Geologist served as chairman of a Science Service committee to make plans for office and laboratory space in the South Mall. In order to meet needs of the next 10 to 15 years, staff, space, and budget should be about three times the present level.

The oil and gas office at Wellsville was expanded by the addition of two small offices which will be available for visitors who wish

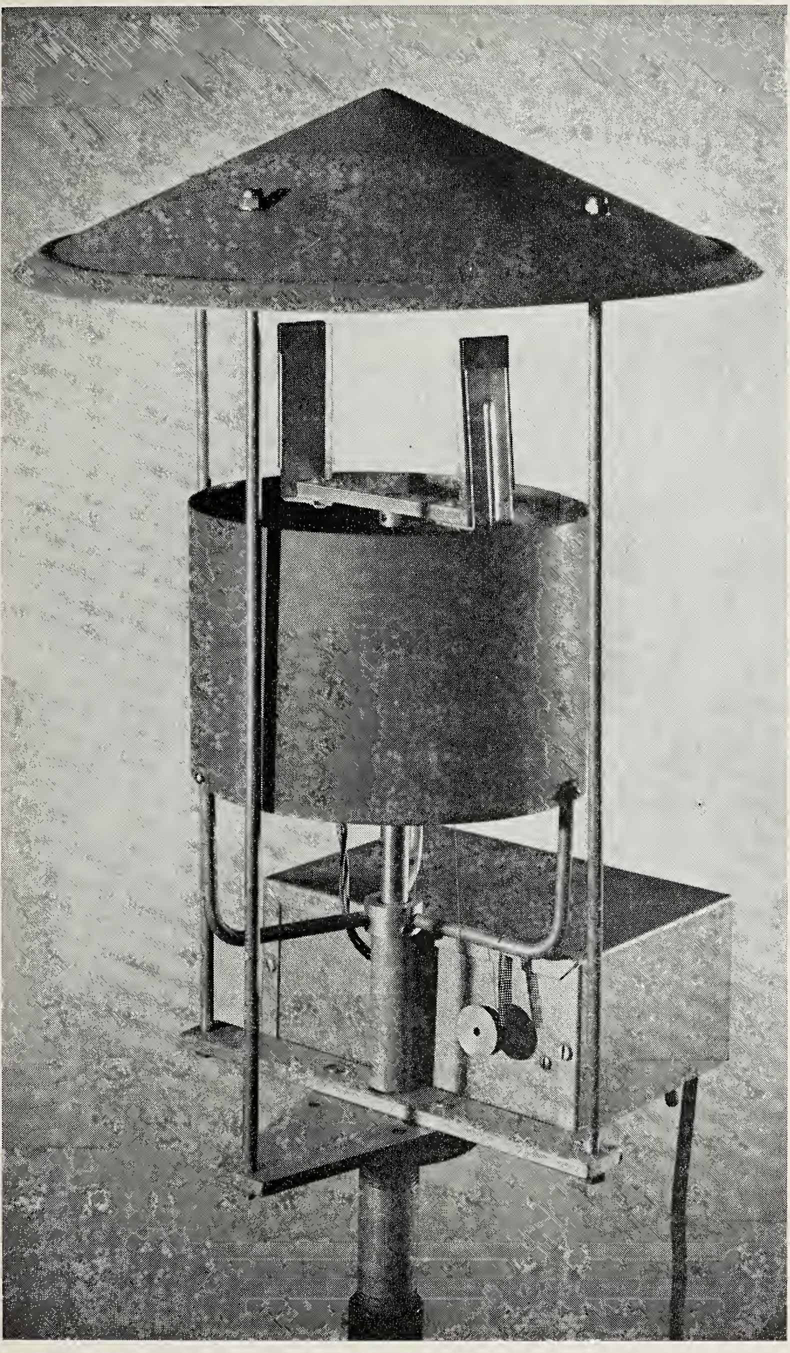

Figure 4. The intermittent rotoslide pollen sampler is widely used for obtaining the pollen count and for research in aerobiology.

to make microscopic studies of well cuttings. There is also additional space for cutting and storing well samples. A small display of minerals and rocks of interest to visitors has been prepared.

Collections of Cricoconarids in Devonion and Silurian strata have been made by the State Paleontologist. They will be used in a study of the morphology, paleoecology, and stratigraphic usefulness of this extinct group of mollusks. The State Paleontologist also studied and photographed a new edrioasteroid from the Manlius Limestone.

Stratigraphic sections on Crane Mountain, in the North Creek Quadrangle, were measured by the Associate Scientist (Geology). This mountain appears to have important significance for the interpretation of Adirondack geological history.

Preliminary skeleton logs of all wells through the Onondaga and deeper in New York State have been completed by the Senior Scientist (Geology). Eventually, the results will be used to update Bulletins 373 and 390. Considerable time was spent checking data for the project on subsurface formations below the Trenton in New York State.

A collection of Silurian Lower and Middle Devonian conodonts is being assembled by the Senior Scientist (Paleontology), in order to establish zonation within rocks of these periods. The collection now includes conodonts from three Silurian formations, twelve Lower Devonian units, nine Middle Devonian units and four Upper Devonian horizons.

A preliminary report on the suitability of the Restof mine for storage of art objects in case of enemy attack was compiled by the Scientist (Geology). Gas samples from the mine were collected for analysis at the Pittsburgh laboratory of the U. S. Bureau of Mines.

The following projects were undertaken by temporary personnel:

A microscopic study was completed of all well samples in the Museum collection for those New York State wells penetrating the interval between the Trenton limestone and the Precambrian basement. This comprehensive study will permit a more valid correlation of the subsurface units in the State and should lead to a much clearer understanding of the subsurface stratigraphy. Members of the permanent staff assisted in this interpretation.

Geologic mapping in the four 7½-minute quadrangles which make up the Tarrytown 15 minute quadrangle was continued. A structural analysis of the New York City group of rocks in this area is developing, which indicates multiple folding from different directions during several mountain-building periods. Interpretation of this extremely complex structure will be a major contribution to the geology of the New York City metropolitan area.

Extensive collections of New York State rocks (particularly in the Adirondacks and the Hudson Highlands) were made, in order to study the form and apparent origin and genesis of zircon, an important accessory mineral which is not destroyed during orogenic episodes.

Mapping in the Berlin quadrangle was continued as a contribution to the understanding of Taconic geology. The first Middle Cambrian rocks in New York State were found, as was an extensive trilobite fauna in Lower and Middle Cambrian rocks. The trilobites are being studied at Johns Hopkins University, and it is already apparent that a great many new genera and species will be described.

Paleoecological investigations of the Helderberg Limestones in central and eastern New York, based on a careful lithological study, were continued. The results will be correlated with earlier findings on the stratigraphy of the Late Cayugan and Helderbergian rocks (Bulletin 386).

Extensive collections of Middle and Upper Devonian vascular plant remains from new exposures in the Catskills were made. The material will be studied at Cornell University and the specimens eventually deposited in the Museum collections.

A map of the glacial geology of western New York between Lake Erie and the Genesee River was essentially completed. It will be published eventually as one of the series on the same base as the State Geologic Map.

A number of radiometric age determinations on rocks of the Adirondacks and the Hudson Highlands was also carried on.

John G. Broughton
State Geologist

The Museum

The staff of the New York State Museum has completed another year of care for the scientific collections and of educational service to the public.

THE PUBLIC

Total attendance in the exhibit halls was about 222,500; an increase of four percent over the previous year. This figure was based on an estimate of 150,500 persons on the 253 weekdays and 38,200 for the 52 Saturdays, plus actual counts of 2,759 on the five holidays and 11,059 during the 21 Sundays that the Museum was open. A change of openings from summer to spring-fall months, initiated in 1962-63, was continued. About twice as many people took advantage of this schedule as compared with visitation in summer during previous years. Excellent publicity material on the Sunday as well as regular weekday openings was distributed to radio and TV stations by the Radio-TV Bureau of the Department of Commerce.

More than 100 different books, pamphlets, kits, and other items were carried at the Sales Desk in the foyer. The stock was increased to include postcards and new colored slides of some exhibits. Each item has been chosen on the basis of its educational value or capacity to stimulate intellectual and scientific curiosity. The offerings aroused so much interest that a portion of the proceeds from the yearly sales total of $6,655 was devoted to hiring a part-time attendant to handle the sales and release the Museum guards for patrolling the halls and performing other duties.

Service to visitors was improved by building an additional coatroom to supplement the very inadequate space which was often piled high with the outdoor paraphernalia of school classes. Waste space under the cliffs of the Gilboa Fossil Forest exhibit was utilized. Here, behind the Sales Desk, a room was built and fitted with hangers and a clothes-receiving bench. The two rooms can accommodate the belongings of 200 visitors. Outside the entrance is a wall cartoon showing a snowshoe hare "jumping" out of its winter coat, a deer fawn "losing" its spots in autumn, and other natural history examples of "coat shedding" in caricature.

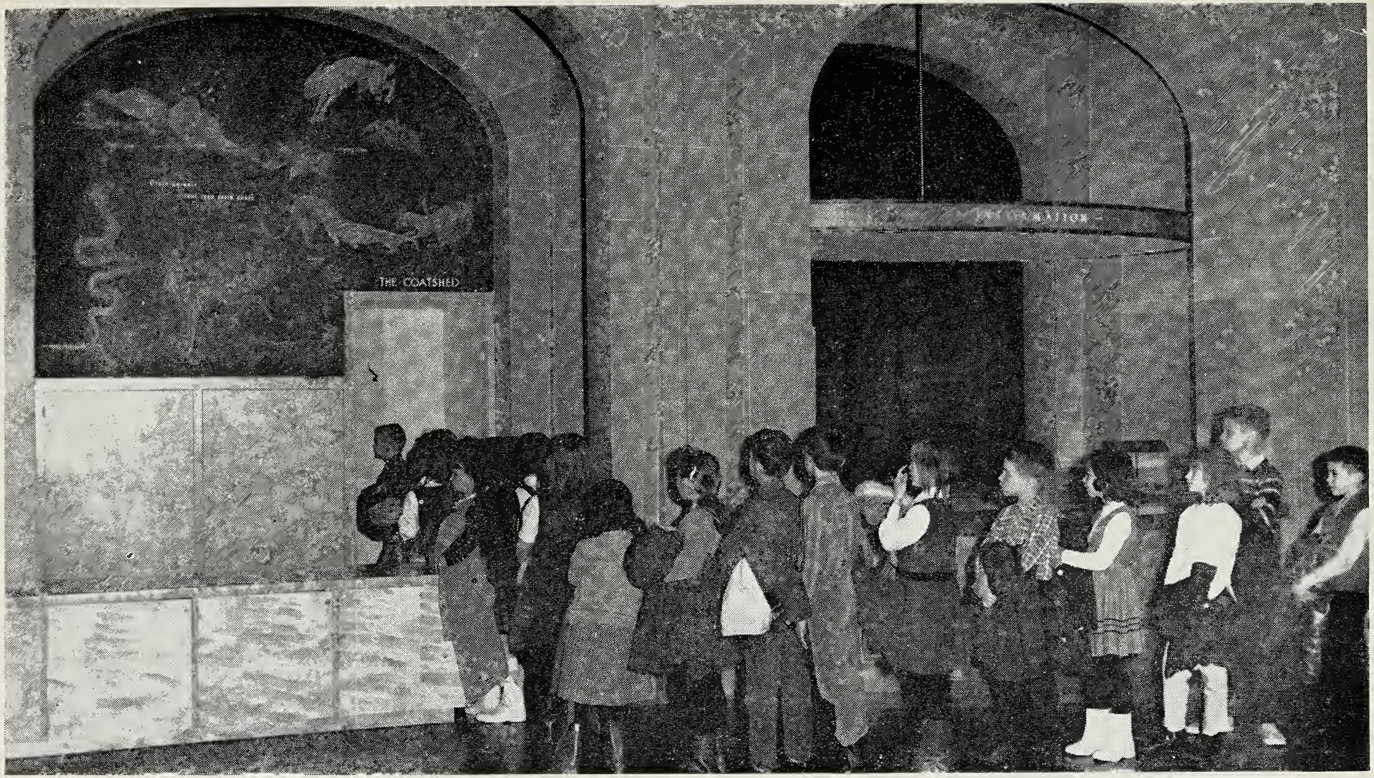

Figure 5. Even before entering the classroom, these winter visitors learn a lesson on adaptation to environment.

In conjunction with work on the second coatroom, the pumping system for the stream in the fossil forest exhibit was completely redesigned. A new pump was installed in a soundproofed compartment under the artificial ledges of the diorama. The old pump, which was noisy and prone to break down, was removed from the first coatroom where it had been an annoyance for many years.

EXHIBITS

The outstanding accomplishment in exhibition was the completion, after two years of planning and preparation, of a description of the history and applications of bird art to science. This display was installed in two especially designed cases, each 45 feet in length. By necessity, they were located in the two corridors between the Rotunda and Biology Hall and separated by a large light well. Hopefully, they can be brought together within a few years in a new building. The exhibit was planned by two Scientific Aides, Mrs. Aileen Merriam and Richard L. Scheffel; design and assembly were accomplished by Theodore P. Weyhe, Museum Exhibits Designer, assisted by Robin D. Rothman, Museum Technician, and all members of the exhibits-preparation staff. The task involved manufacture and assembly of 150 pictures, reproductions, and other objects, plus 170 labels. Original paintings were contributed by the artists, Richard E. Bishop of Philadelphia, Pa., Don Eckelberry of Babylon, N. Y., Francis Lee Jaques of St. Paul, Minn., and Roger Tory Peterson of Old Lyme, Conn. Books, plates, and other material were given by 19 other donors.

Two permanent exhibits were completed and installed in Paleontology Hall. The colorful display of protistids ("first" animals) and a fine restoration of Devonian marine life in its natural setting were planned by the State Paleontologist, Donald W. Fisher, designed by the Museum Exhibits Designer, and executed by Louis J. Koster, Senior Museum Technician, and his associates. Another diorama concerning the black shale environment of the Ordovician period was nearing completion at the end of the year. A figure of an Indian child, planned several years ago and sculptured by the Senior Museum Technician, was finished and installed in the Iroquois Bark House. Exhibits were made of the fulvous tree duck (an aberrant species which showed up recently on Long Island) and of "Ge-oddities" (three rare minerals of the northwestern Adirondacks). The old display of fluorescent minerals was rebuilt and furnished with new lighting. Renovation of the extensive series of New York

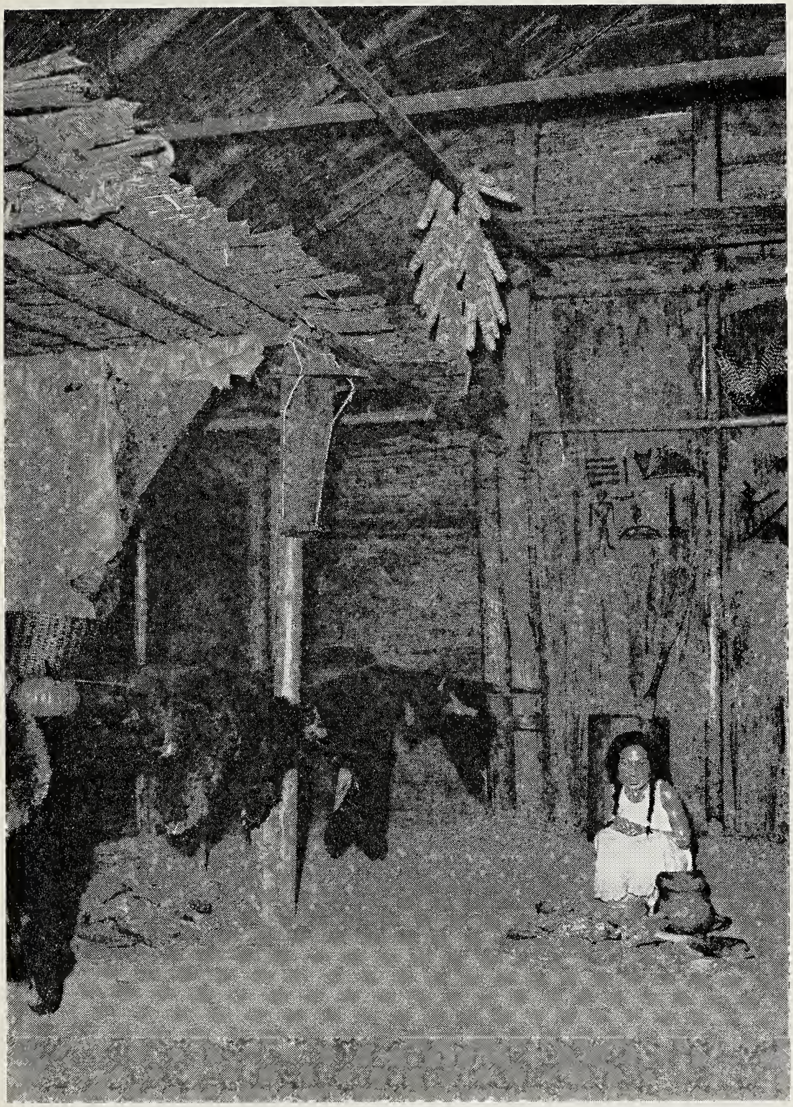

Figure 6. The Indian child sculptured by Louis J. Koster, Senior Museum Technician, resides in the Iroquois Bark House.

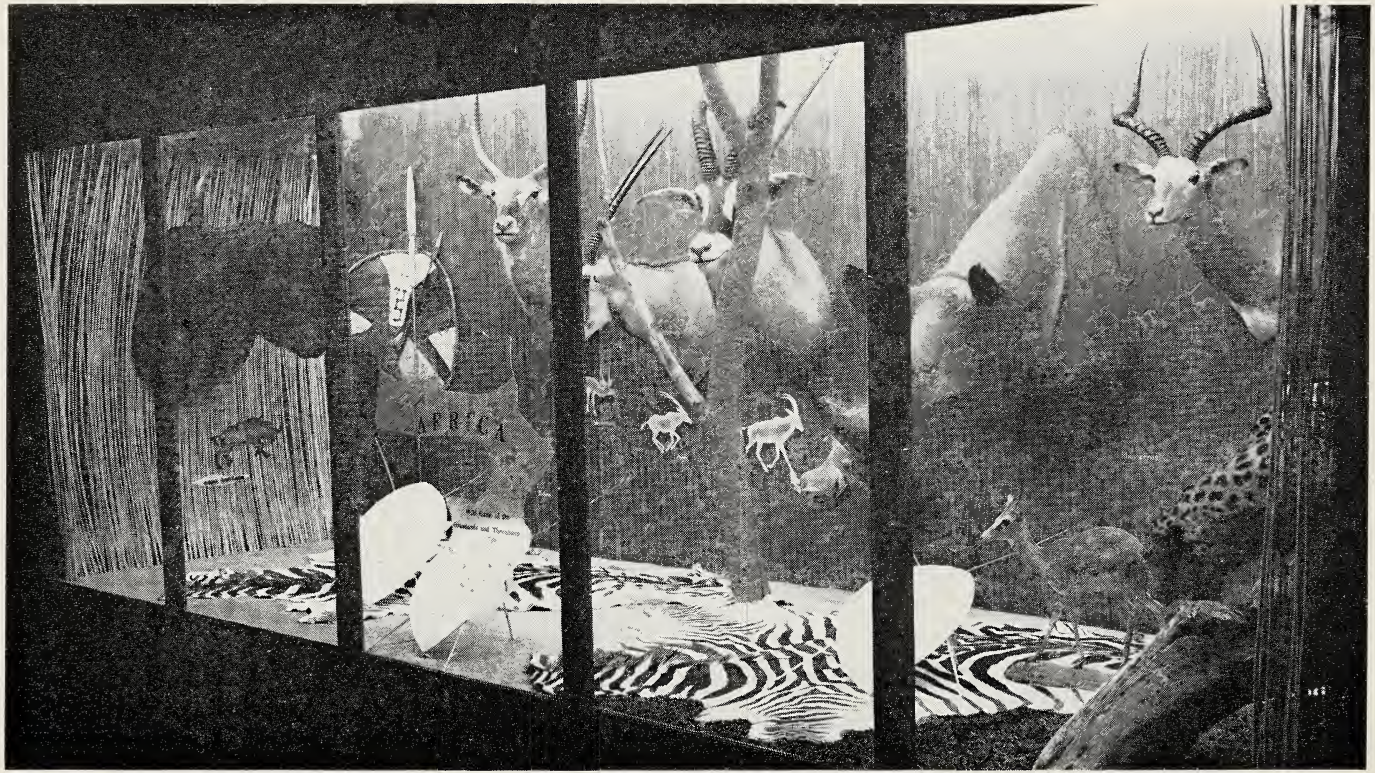

Figure 7. What at first appears to be an exhibit of trophies turns out as a lesson in conservation. Big game hunters Dr. and Mrs. W. Brandon Macomber, of Albany, carefully avoided collecting those species in danger of extinction.

reptiles continued; specimens of additional species were collected and reproduced in epoxy, and a new facade and canopy were added to give a new look to the old cases.

The exhibit halls were enhanced during the year by two temporary shows. Some two dozen specimens from the Macomber donations of mammals were brought out for a lesson in the conservation of Africa's rapidly vanishing wildlife. For a month, we were privileged to show 20 pieces of animal sculpture by Anna Hyatt Huntington. The loan, which had been arranged with the artist shortly before her death, was carried out by the Mariners Museum, Newport News, Va. Display of the aluminum casts were greatly enhanced by placement on special surfwood paneled pedestals, which were painted black and white and backed by a clump of white birch trees. This setting was originated and designed by the Museum Exhibits Designer.

A final, major change in the exhibition area was effected this year with the dismantling of 92 old exhibits in the former Morgan Hall by Charles E. Gillette, Associate Curator of Archeology. He was assisted by student labor and by volunteers under the Museum Aide Program of the Senior Girl Scouts.

EDUCATION

Improvements were made in the operation of the school education program, a department of the State Museum which during recent years has become increasingly useful in rendering service to the public. In a reappraisal of the role of education within the Museum as a whole, it is realized that interpretation of the Museum to the public is an area of prime responsibility. To make the most effective use of resources and personnel, however, services must be tailored to particular needs. At present, the schoolchildren and teachers of New York State appear to be that segment of the public most in need of instructional service and also in the best position to take advantage of it. Under Jennifer Chatfield, Associate Curator of Interpretation, and C. Michael Darcy, acting Museum Education Supervisor, the workshop program for teachers was improved and expanded. One of the sessions was an aerial field trip which enabled participants to obtain a graphic concept of the geology and the patterns of historical development and land use of the Capital District. Fifty teachers (who paid personally for the half-hour flights) were thoroughly briefed and furnished with maps for recording impressions which would enable them later to do a better job of

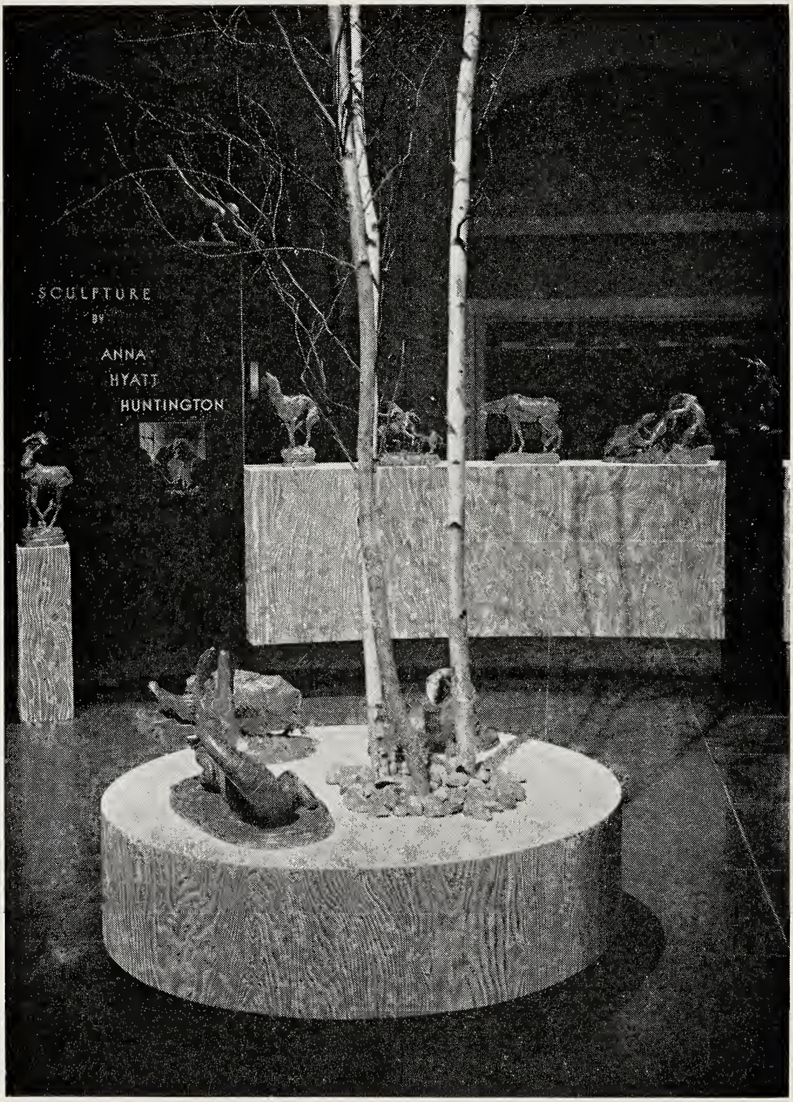

Figure 8. A diversion from pure learning, an exhibit of animal sculpture offered aesthetic enjoyment as well.

class instruction. Much information was contributed to the workshop program by the scientific staff of the State Museum and Science Service. Lecture-demonstrations, supplementing those by the Museum Instructors, were given by Messrs. Borst, Connor, Fisher, Gillette, Reilly, and Wilcox and by William L. Lassiter, Division of Archives and History.

This program for improving science instruction in schools should be extended in the State. Because of lack of personnel and funds for staff travel, teacher workshops are restricted to the Capital District.

By using the mails, however, other educational services have been made available through an informative and idea-provoking newsletter to some 3,000 teachers throughout New York State. This letter serves to keep teachers and other interested visitors aware of the Museum's program and what it can offer them. More loan kits of scientific materials have been prepared and additional "leaflets" up to 74 pages in length have been written or are in preparation. All of these materials, it is hoped, will enable teachers to do a better job of teaching.

For the third summer, a series of films on nature and natural resources conservation was presented as a free service to the public. Drawing a total audience of 950 persons (50 percent larger than that of the previous season), it was necessary to move from the overcrowded classroom to improvised seating in the old History Hall.

The Museum education staff received several Science Congress award winners and, with the assistance of exhibits technicians, installed their displays in Orientation Hall for several months' viewing. Instruction on special subjects for visiting school classes was contributed by curators. Dr. Reilly was especially active in lecturing to youthful biology groups, both in the Museum and elsewhere in the region. Several Girl Scouts performed clerical chores in the education office (and also worked at the public information desk and in archeology collections). We maintained a listing in the Albany Junior League's "opportunities for public service" without attracting volunteers.

Science classes for school groups continued with one significant change. In an effort to improve instruction for both children and teachers using our available staff and facilities, general tours of exhibits were dropped. Practically all such requests in the past had been made on behalf of groups of youngsters who came to the Museum with no advance preparation for learning and as only one stop in an excursion to their capital city. (In 1962-63, general tours were given to 3,500 individuals.) As teacher demands for instruction

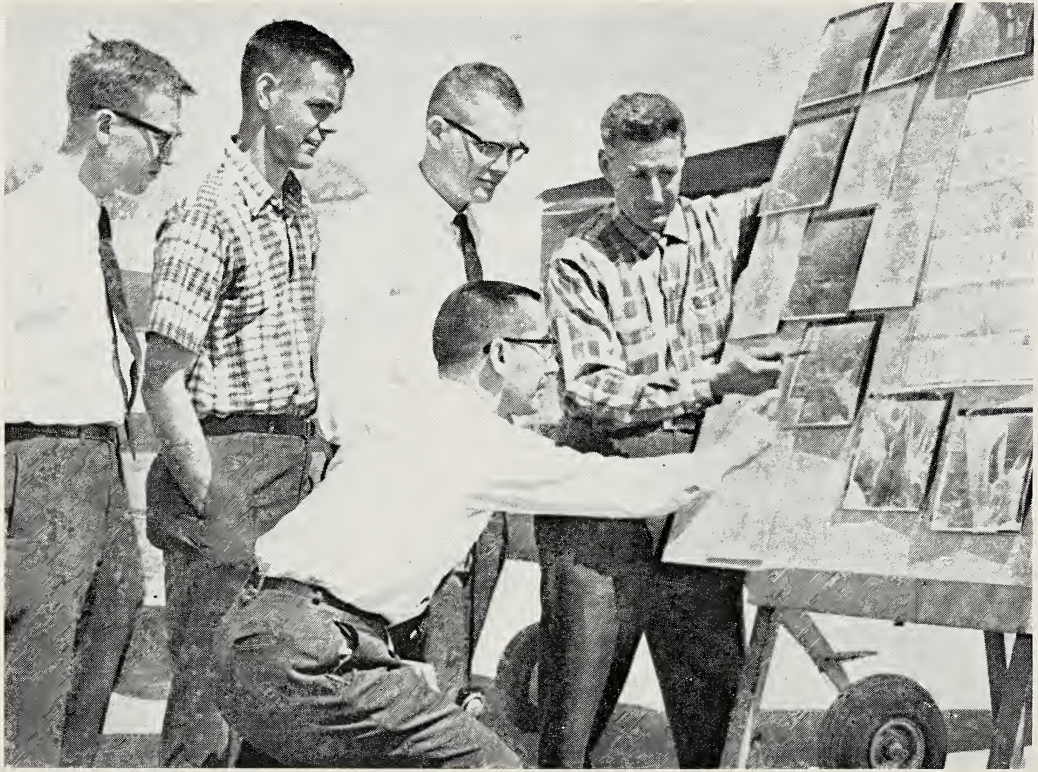

Figure 9. Teachers are briefed before an aerial field trip to study patterns of land use in the Capital District. (Knickerbocker News photo)

and material to supplement the established school curriculum had increased in recent years, it now seemed essential to concentrate efforts in this area.

Our records show an increase in the number of visiting children in groups of all types of approximately 5,000, almost 15 percent larger than in the previous year. Classes from schools also increased in the same proportion. Unfortunately, due to delay in filling two vacancies resulting from resignations of members of the teaching staff, the latter was undermanned over 25 percent for the first half of the Museum's school year. Although instructors carried at least 10 percent heavier teaching loads, many requests from schools for instruction of their classes were necessarily refused. Primarily for this reason, the number of children registered in the Museum education program was 3,500 to 4,000 less in 1963-64 than in the preceding year, a decline of about 15 percent. This loss of pupil instruction was more than balanced by expansion of service to teachers in workshops and in statewide distribution of teaching aids.

SCIENTIFIC COLLECTIONS

In the collections, highlights were as follows: Archeology, further progress was made in reidentifying articles from the Morgan and Beauchamp collections; botany, almost 5,000 specimens accessioned and maps completed for all species of mosses represented in the Herbarium; geology, the Trainer collection of minerals, donated to the State Museum in 1949, was cleaned, cataloged, and prepared for loan to the newly organized Southeast Museum at Brewster; paleontology, 27 new types, some 700 New York bryophytes and graptolites from Germany and Czechoslovakia were added to this collection, which continued to be heavily used by scientists from other institutions; zoology, over 700 items added, and a long-needed rearrangement of bird nests, osteology, mammals, and alcohol-preserved collections began following installation of steel shelving. The curator of geology continued research on clay minerals in the Lower Devonian carbonate rocks of the upper Hudson Valley, and the curator of entomology carried on his studies of the leaf beetles. The last named completed and turned in for editing a 350-page synopsis of one of the subfamilies, the Galerucinae, and the curator of botany submitted his manuscript entitled "A Check List of Grasses of New York State." Both works will be published as Museum Bulletins.

GIFTS RECEIVED

Among numerous gifts from thoughtful and generous donors were a fine collection of minerals from the southern Adirondacks by Elmer B. Rowley, Glens Falls, a select group of minerals from Ivigtut, Greenland, by Harold Newman, Lower Burrell, Pennsylvania, an outstanding hexagonite specimen by William Rocco, Scotia, and 20 specimens of African mammals which were given by Dr. and Mrs. W. Brandon Macomber, Albany. The latter also had mounted for exhibition, without expense to the State Museum, the head and neck of a black rhinoceros which they had donated in 1958. We also received a mounted tuna, 9 feet, 7½ inches long and 890 pounds—a record at the time it was caught in 1939—as a gift from the J. A. Manning Paper Company of Green Island. After minor repairs, the tuna was placed on the west wall of Biology Hall near the Hecht collection of fishes.

LIBRARY

The State Museum maintains a small library containing files of its own publications, publications of other N. Y. State agencies, publications of other state surveys, other Museums, and federal documents relating to science, as well as books and periodicals which are used frequently by the staff. The major responsibility of the librarian is in the reference field. Increasingly, she and her one part-time clerk are finding it difficult to keep up-to-date with the expanding volume of scientific publications. Another complicating factor is inadequate room. Although the former quarters in the main building were crowded, the Museum library was moved 4 years ago to a room in the Annex that was 25 percent smaller. The only available storage space, then and now, is a city block and two floors distant. As a result, time and effort is expended in withdrawing and returning items which are required for use by the staff but for which room is not available in the Museum library.

STAFF ENRICHMENT

A grant of funds obtained by the American Association of Museums made it possible for two of our staff, curator of archeology Charles E. Gillette and education instructor Judith A. Drumm, to attend the 6-weeks session of the Institute in Anthropology for Museum Personnel at the University of Arizona. The opportunity

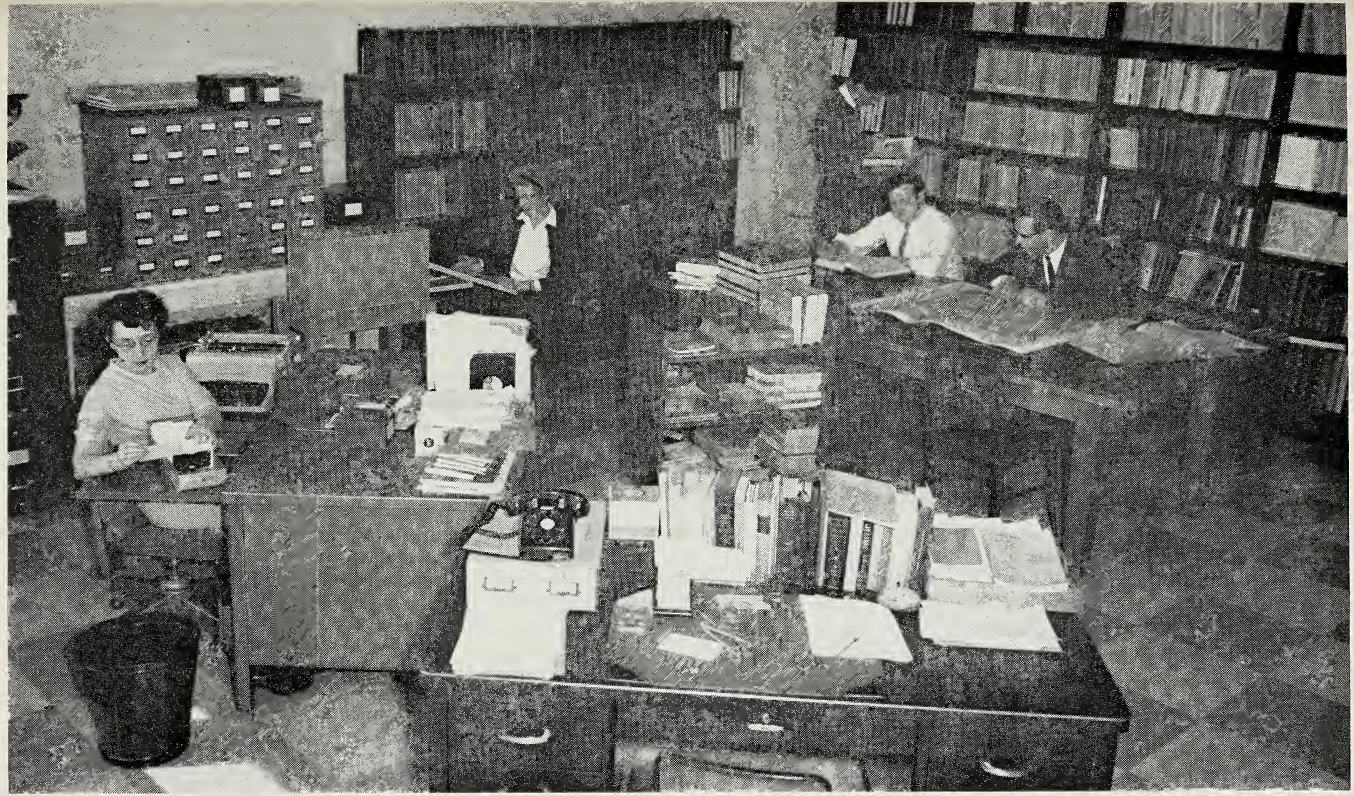

Figure 10. Present facilities do not permit an increase in library resources for a dynamic scientific organization. The juxtaposition of clerical activities and reference reading is not ideal.

to brush up on the science and preservation-curatorial methods and the exposure to the ideas of fellow workers were highly advantageous. Three members of the staff, Miss Chatfield, Miss Rothman, and the writer, participated in seminars on Africa which were arranged by the Department's Office of Foreign Area Studies with a grant from the New World Foundation. This, too, was a broadening experience.

NEW BUILDING PLANNING

Several man weeks of time were spent by the Museum staff in drawing up space requirements for a new home on the South Mall. It appears that the State Museum and Science Service will require approximately 400,000 square feet to house the present staff and such additional programs as can be expected during the next two or three decades and to provide exhibits in the natural and physical sciences which are adequate for educational needs. The Assistant Director continued his studies of buildings for features which may be adaptable to use in our plans. For this purpose, trips were made to Chicago (Natural History Museum and Art Institute), Milwaukee (Public Museum and Art Museum), and St. Louis (Museum of Westward Expansion, Science Museum, and Missouri Botanical Garden's Climatron). The State Museum's education staff contributed to the fact-gathering effort by conferring with about 200 teachers in 20 schools of the Albany area to obtain comments on the educational services which would be expected in a new museum. (Results of this survey were also used in revamping our current education program to obtain maximum usefulness.)

MISCELLANEOUS

Among the activities of the writer which were outside of his official duties but related to them was the completion of a survey and report on the status of the cougar, grizzly, and wolf in North America for the New York Zoological Society and the Boone and Crockett Club.

VICTOR H. CAHALANE
Assistant Director, State Museum

Appendix A

1964 GRADUATE STUDENTS HONORARIA RECIPIENTS

Entomology

FITZGERALD, TERRENCE D., State University College of Forestry at Syracuse University Bionomics of a lepidopterous bark miner in ash trees	$540
WING, MERLE W., Cornell University Taxonomic revision of Nearctic ant genus *Acanthomyops*	600

Geology

FULLERTON, DAVID S., Yale University Glacial geology of the Upper Mohawk Region, New York	540
GROSVENOR, FLORENCE A., University of Rochester Brachiopoda of the Rondout formation in the Rosendale quadrangle	300
HELENEK, HENRY L., Brown University Investigation of origin and metamorphic evolution of major rock units in the Hudson Highlands	420
* KIRCHGASSER, WILLIAM, Cornell University Stratigraphy and paleoecology of the Cashaqua shale formation in central and western New York	300
LINDHOLM, ROY C., Johns Hopkins University Petrology of the Onondaga limestone	420
MCCONNELL, CARL L., Yale University Stratigraphic study of the Grenville metasedimentary sequence in eastern Adirondacks	480
* TURNER, BRIAN B., Yale University Geology of southern half of Schroon Lake quadrangle	480

Zoology

DUNHAM, DAVID W., Cornell University Behavioral study of rose-breasted grosbeak	480
WOLFE, JAMES L., Cornell University Certain aspects of population dynamics of the eastern chipmunk	600
	$5,160

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* Renewal.

Appendix B

Conferences and professional meetings in which the Museum and Science Service staff participated:

American Anthropological Association, annual meeting, San Francisco, Calif.—Fenton, Ritchie

American Anthropological Association, board meeting, Detroit, Mich.—Fenton

American Association of Museums, annual meeting, St. Louis, Mo.—Cahalane

American Association of Petroleum Geologists, Toronto, Can.—Fisher, Kreidler

American Bryological Society Foray, Adirondack Mountains—Smith, S. J.

American Committee for International Wildlife Protection, annual meeting, New York, N. Y.—Cahalane

American Indian Ethnohistoric Conference, Newberry Library, Chicago, Ill.—Fenton

American Institute of Biological Sciences, annual meeting, Amherst, Mass.—Connor, De Groot, Lewis, Ogden, Vormevik

American Mosquito Control Association, annual meeting, Chicago, Ill.—Collins

American Ornithologists' Union, annual meeting, Gainesville, Fla.—Palmer

Association of Science Museum Directors, Springfield, Ill.—Cahalane

Atmospheric Biology Conference, Minneapolis, Minn.—Ogden

Atmospheric Sciences Research Center, Whiteface Mountain—Smith, S. J.

Boone and Crockett Club, annual meeting, New York, N. Y.—Cahalane

Central States Anthropological Association, Milwaukee, Wis.—Fenton

Commissioner's Staff Conference, Diamond Point, N. Y.—Fenton

Conference of Pennsylvania Geologists, Stroudsburg, Pa.—Kreidler, Rickard

Cornell University Teachers Workshop, Schakleton Point, Oneida Lake, N. Y.—Reilly

Defenders of Wildlife, annual and executive committee meetings, Washington, D. C.—Cahalane

Directors of Systematic Collections, 8th Conference, New York, N. Y.—Fenton

Eastern States Archaeological Federation, Philadelphia, Pa.—Gillette

Entomological Society of America, annual meeting, St. Louis, Mo.—Collins

(Eastern Branch), annual meeting, New York, N. Y.—Collins

Federation New York State Garden Clubs, annual meeting, Cooperstown, N. Y.—Reilly*

Fort Ticonderoga Memorial Ceremony, Fort Ticonderoga, N. Y.—Fenton

Geological Society of America, annual meeting, New York, N. Y.—Broughton, Davis, Fisher, Isachsen, Rickard

Massachusetts Historical Society, Boston, Mass.—Fenton

National Academy of Sciences, National Research Council, Philadelphia, Pa.—Fenton

National Museum of History and Technology, Washington, D. C.—Fenton

New York Academy of Sciences, Geologic Sciences, New York, N. Y.—Isachsen*

New York State Archeological Association, Auringer-Seelye Chapter meetings, Fort Edward, N. Y.—Funk*, Gillette*

New York State Archeological Association, annual meeting, West Point, N. Y.—Funk, Gillette, Ritchie*

New York State Archeological Association, Mid-Hudson Chapter meeting, Rhinebeck, N. Y.—Funk*

New York State Archeological Association, Van Epps-Hartley Chapter, winter meeting, Albany, N. Y.—Funk, Gillette, Ritchie*

New York State Archeological Association, Van Epps-Hartley Chapter, annual meeting, Fonda, N. Y.—Gillette

New York State Association of Museums, Council meeting, New York, N. Y.—Fenton

New York State Department of Health, Interdepartmental Health and Hospital Council, Committee on Pesticides, Albany, N. Y.—Collins

New York State Geological Association, Syracuse, N. Y.—Broughton, Fisher, Kreidler, Rickard

New York-Vermont Interstate Commission on Lake Champlain Basin, Vergennes, Vt.—Broughton, Davis

Northeast Museums Conference, West Point, N. Y.—Fenton

Northeastern Forest Pathology Workshop, Morgantown, W. Va.—De Groot

Northeastern Forest Pest Council, annual meeting, Boston, Mass.—Collins, Connola, De Groot

Northeastern Forest Tree Improvement Conference, New Brunswick, N. J.—Connola

Paleontological Research Institute, Ithaca, N. Y.—Fisher and Rickard

Peck Mycological Foray, Oneonta, N. Y.—De Groot, Smith

Sigma Xi, Albany Club—Ritchie*

Society for American Archeology, Chapel Hill, N. C.—Ritchie*

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* Gave talk.

State Natural Resources Committee for Cornell and Syracuse Universities, Ithaca, N. Y.—Cahalane, Fenton

U. S. Department of Agriculture, Interagency Conference on *Bacillus thuringiensis* (Gypsy moth pathogen), New Haven, Conn.—Collins, Connola

U. S. Department of Health, Education and Welfare, Biennial Vector Control Conference, CDC, Atlanta, Ga.—Collins

Wayne State University, Detroit, Mich.—Ritchie*

Wenner Gren Foundation of Anthropological Research, Conference on Africa, New York, N. Y.—Fenton

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* Gave talk.

Appendix C

Cooperative Work (Service): Extension program by the staff of State Museum and Science Service to various groups:

Adirondack Mountain Club—Cahalane, Reilly*
Albany Academy for Girls—Reilly*
American Folklore Society—Fenton
American Museum of Natural History, Libraries and Collections—Palmer
American Telephone and Telegraph Company—Kreidler
Appalachian Trail Conference—Cahalane
Blue Creek Garden Club—Reilly*
Brown University—Isachsen
Capital Area School Development Association—Gillette
Cayuga Museum of History and Art—Fenton*
Chatham High School Nature Club—Reilly*
Colonie Cub Scouts—Reilly*
Connecticut Entomological Society—Jamnback
Cornwall Museum—Reilly*
Dartmouth College, Department of Geology—Isachsen, Rickard
East Greenbush Science Fair—Reilly*
Fort Hunter Elementary School—Reilly*
Fort Plain Museum—Gillette
Fredonia College Biology Club—Reilly*
Harpur College Anthropology Club—Fenton*
Hudson Valley Girl Scout Council—Gillette
Independent Petroleum Association of America—Kreidler
Institute for Iroquoian Studies, Brantford, Ontario, Can.—Fenton
Institute for Iroquois Research (Symposium)—Fenton
International Congress of Anthropological and Ethnological Sciences, Permanent Council—Fenton
Interstate Oil Compact Commission—Kreidler
Joint Legislative Committee on Indian Affairs—Fenton
Kinderhook Memorial Library—Fenton*
National Herbarium of Canada—Smith, S. J.
National Museum of Canada—Fenton
National Park Service—Fenton, Ritchie
Natural Resources Committee of Cornell and Syracuse Universities—Cahalane
New Jersey Geological Survey—Rickard
New York Botanical Garden—Smith, S. J.
New York State Bureau of Criminal Investigation—Gillette, Smith, S. J.
New York State Department of Agriculture and Markets—Smith, S. J.

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* Gave talk.

New York State Department of Commerce—Kreidler, Smith, S. J.
New York State Department of Conservation—Kreidler
New York State Department of Health—Fenton
New York State Department of Public Works—Fenton, Funk
New York State Executive Department—Kreidler
Niagara Mohawk Power Corporation—Kreidler
Pok-O-Moonshine Counselors, Willsboro—Reilly*
Rensselaer Polytechnic Institute—Rickard
Roberson Memorial Center, Committee of 100—Fenton
Robert A. Taft Sanitary Engineering Center—Lewis
Rochester Academy of Science—Cahalane
School for Christmas Tree Growers—Connola
Seneca Nation of Indians at Salamanca—Fenton
State University of New York at Albany—Smith, S. J.
State University College at Geneseo—Smith, S. J.
State University College of Agriculture at Cornell University—Smith, S. J.
State University College of Forestry at Syracuse University—Collins, Connola, Smith, S. J.
Staten Island Institute—Smith, S. J.
Summer Institute in Anthropology for Museums, Tucson, Ariz.—Drumm, Fenton, Gillette
Syracuse University, Department of Anthropology—Ritchie
University of Rochester—Rickard
University of Toronto—Fenton
University of Waterloo, Ontario, Can.—Fenton
University of Wisconsin—Fenton*
U. S. Bureau of Mines—Kreidler
U. S. Fish and Wildlife Service—Ritchie
U. S. Public Health Service, New York City—Collins
WHUC Radio Station—Reilly*
Wildcliff Youth Museum—Fenton, Reilly

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* Gave talk.

Appendix D

COOPERATING AGENCIES

A continuing function of the Museum and Science Service is to cooperate with agencies and organizations concerned with museum and research activities in this and other states, with the governments of the United States and Canada, with universities and industry in the discovery, analysis, and dissemination of scientific information. These contacts are frequently of reciprocal services, and they arise often out of the personal contacts of the staff and, if so listed, would measure individual participation, but they are here tabulated for the organization.

Brown University
Bryn Mawr College
Colgate University
Cornell University
Fort Klock
Harpur College
Huyck Preserve
George Landis Arboretum
National Commercial Bank & Trust Company
New York State Department of Commerce
New York State Department of Conservation
New York State Department of Health
New York State Department of Labor, Division of Industrial Hygiene
New York State Department of Public Works
Syracuse University
U. S. Geological Survey

Appendix E

PROFESSIONAL AFFILIATIONS:

Offices held by staff

Adirondack Mountain Club, Vice-President—Cahalane
American Anthropological Association, executive board—Fenton
American Committee for International Wildlife Protection, Vice-Chairman (reelected)—Cahalane
American Ornithologists' Union, Committee on Bird Protection, Chairman—Cahalane
Defenders of Wildlife, President—Cahalane
Federation of New York State Bird Clubs, Research and Publications Committee, Chairman—Reilly
Nature Conservancy, Eastern New York Chapter, Trustee—Cahalane
New York State Archeological Association, Van Epps-Hartley Chapter, Treasurer—Gillette
Shaker Museum, Trustee—Fenton

Publications

Six Museum bulletins, including an annual report, were printed in 1963-64. They totaled 814 pages of text and 111 plates, figures, charts and maps. An Educational Leaflet comprising 30 pages and 11 figures was also printed; a second with 78 pages and 14 illustrations was reproduced by the multilith process. Six miscellaneous publications of the newsletter type were issued in multilith: three numbers of the *New York State Geogram* totaled 48 pages, and three pamphlets containing current information of interest to teachers contained about 20 pages. Members of the staff published 12 papers, totaling about 75 pages, in outside books, journals, etc.

At the close of the year, six manuscripts had been accepted for publication. One was designed for the map and chart series; the others, totaling about 900 manuscript pages, will be Museum bulletins.

State Museum and Science Service

PUBLICATIONS

1963 The Empire State Geogram. Triannual Newsletter of the Geological Survey. 2 illus. Vol. 2, No. 1, Fall, 1963. 16pp.
1964 The Empire State Geogram. Triannual Newsletter of the Geological Survey. 3 illus. Vol. 2, No. 2, Winter, 1964. 16pp.
1964 The Empire State Geogram. Triannual Newsletter of the Geological Survey. 2 illus. Vol. 2, No. 3, Spring, 1964. 16pp.
1964 125th Annual Report of the New York State Museum and Science Service, July 1, 1962-June 30, 1963. N. Y. State Mus. & Sci. Serv. Bull. No. 395. 53pp.
1964 Museum Education. Monthly Newsletter of the Education Office. Vol. 1, No. 5, April, 1964. 4pp.
1964 Museum Education. Monthly Newsletter of the Education Office. Vol. 1, No. 6, May, 1964. 4pp.
1964 State Museum Services: Teacher's Guide. 12pp.

Connola, D. P. & Wixson, E. C.
1963 White pine weevil attack in relation to soils and other environmental factors in New York. N. Y. State Mus. & Sci. Serv. Bull. 389. 80pp., 4 pl., 13 figs., 3 maps

Darcy, C. M.

1964 Classroom animals: their care and maintenance. Educational Leaflet Series No. 17. 78pp., 9 figs., 5 illus.

Kreidler, W. L.

1963 Selected deep wells and areas of gas production in western New York. N. Y. State Mus. & Sci. Serv. Bull. No. 390 404pp., tab., map

MacClintock, Paul & Stewart, D. P.

1963 Pleistocene geology of the St. Lawrence Lowland. N. Y. State Mus. & Sci. Serv. Bull. 394. 152pp., 40 figs., map

Muller, E. H.

1963 Geology of Chautauqua County, New York. Part II, Pleistocene Geology. N. Y. State Mus. & Sci. Serv. Bull. No. 392. 60 pp., 15 figs., 4 tab., map

Scheffel, R. L.

1964 Bird art in science. Educational Leaflet Series No. 16. 30pp., 11 figs.

Tesmer, I. H.

1963 Geology of Chautauqua County, New York. Part I, Stratigraphy and Paleontology (Upper Devonian). N. Y. State Mus. & Sci. Serv. Bull. 391. 65pp. 5 pls., 17 figs., 2 tab., map

In Outside Media

Broughton J. G. & Stewart, H. G., Jr.

1963 Geology and hydrology of Western New York Nuclear Service Center. Geol. Soc. Amer. (Abstract)

Cahalane, V. H.

1963 A preliminary study of distribution and numbers of cougar, grizzly and wolf in North America. N. Y. Zoological Society. 12pp.

De Groot, R C.

1963 Wood extractive content and *Fomes pini* infection of Eastern white pine. (Abstract). Phytopathology 53: 873

Fenton, W. N.

1963 Horatio Hale (1817-1896): introduction to the Iroquois book of rites. Univ. of Toronto Press, vii-xxvii

———

1963 The Seneca green corn ceremony. The Conservationist, v. 18, No. 2 (Oct.-Nov.), pp. 20-22, 27-28. N. Y. State Conservation Department

Isachsen, Y. W.

1964 Extent and configuration of the Precambrian in Northwestern United States. Trans. N. Y. Acad. Sci., ser. 2, v. 26, pp. 812-829

Jamnback, H.

1963 Further observation on the effectiveness of chemically treated screens in killing biting midges, *Culicoides sanguisuga* (Diptera: Ceratopogonidae). Jour. Econ. Ent. 56: 719-720

——— & Watthews, T.

1963 Studies of populations of adult and immature *Culicoides Sanguisuga* (Diptera: Ceratopogonidae). Ent. Soc. Amer. 56: 728-732

Kreidler, W. L.

1964 Gas and oil developments in New York State for 1963. Amer. Assn. of Petroleum Geologists, v. 48, No. 6: 778-783

Reilly, E. M., Jr.

1964 New York's spooky big cat. The Conservationist, v. 18, No. 4 (Feb.-Mar.), pp. 2-4. N. Y. State Conservation Department

Rickard, L. V.

1963 Stratigraphy, facies changes and paleoecology of the Lower Devonian Helderberg Limestones and the Middle Devonian Onondaga Limestones. Geol. Soc. of Amer. Guidebook for Field Trip (Nov.)

Smith, S. J.

1963 How to make a dried plant collection. The Conservationist, v. 17, No. 7 (Aug.-Sept.), pp. 48-49. N. Y. State Conservation Department

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The Interrelationships of Three Gall Makers and Their Natural Enemies, on Hackberry (*Celtis Occidentalis* L.)

John Conrad Moser

SMITHSONIAN
[illegible] 1965
LIBRARY

BULLETIN NUMBER, 402

NEW YORK STATE MUSEUM AND
SCIENCE SERVICE

The University
of the State
of New York

ALBANY, NEW YORK

The State
Education
Department

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The Interrelationships of Three Gall Makers and Their Natural Enemies, on Hackberry (*Celtis Occidentalis* L.)

John Conrad Moser

ALBANY, NEW YORK
The University of the State of New York
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Contents

PAGE

1 **ABSTRACT**

3 **INTRODUCTION**

5 **PART I — THE GALL MAKERS**

5 *Pachypsylla celtidisvesicula*

7 *Pachypsylla celtidismamma*

8 *Phytophaga* sp. nr. *spiniformis*

12 **PART II — NATURAL ENEMIES — KEYS, DESCRIPTIONS, AND BIOLOGIES**

12 A. *Natural enemies of psyllid gall makers*

12 Keys to insects associated with galls of *Pachypsylla*

14 *Moserina maculata*

15 *Hypertetrasticus ithacus*

17 *Paralleloidiplosis acernea*

17 *Leptacis* sp.

18 *Psyllaephagus pachypsyllae*

19 *Achrysocharis vesiculis*

21 *Torymus vesiculus*

22 *Torymus pachypsyllae*

22 *Eurytoma semivenae*

23 *Conotrachelus buchanani*

24 Other parasites of *Pachypsylla*

24 B. *Natural enemies of cecidomyiid gall maker*

SMITHSONIAN INSTITUTION DEC 7 1965

PAGE

24 Keys to insects associated with *Phytophaga* sp.

25 *Trichacis* sp.

26 *Torymus diabolus*

27 *Achrysocharis spiniformis*

30 *Tetrastichus nebraskensis*

30 *Eupelmella vesicularis*

31 **PART III — MISCELLANEOUS NOTES ON LIFE HISTORIES AND INTERRELATIONSHIPS**

31 Discussion

33 A method of separating *Torymus vesiculus* and *T. pachypsyllae* by means of the analysis of coveriance

34 Notes on the taxonomic status of *Achrysocharis vesiculis* and *A. spiniformis*

36 Distribution of *Celtis occidentalis* in the drainage of the Cayuga Lake Inlet

37 **SURVEY OF LITERATURE**

39 **ACKNOWLEDGEMENTS**

40 **LITERATURE CITED**

44 **ILLUSTRATIONS**

The Interrelationships of Three Gall Makers and Their Natural Enemies, on Hackberry (*Celtis Occidentalis* L.)

by John Conrad Moser
Graduate Student Honorarium Program*

ABSTRACT

This bulletin describes three hackberry galls, the insects which make them, and 19 of their natural enemies in the Cayuga Valley near Ithaca, N.Y. Two galls were caused by psyllids and the third by a cecidomyiid. The taxonomy, biology, morphology, and distribution of the species are discussed.

Fourteen natural enemies attacked the psyllid gall makers, and five fed on the cecidomyiid gall maker. However, no cecidomyiid parasites were found in psyllid galls, nor were natural enemies of psyllids located in cecidomyiid galls. Whereas most natural enemies attacked only gall makers, three were normally parasites of lepidopterous leaf miners of hackberry, and two fed on a wide range of insects other than those associated with hackberry.

At least three parasites of the psyllid complex were secondary; two were specific to a single primary parasite, and the other fed on all primary parasites as well as the gall makers. Two natural enemies

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* Entomologist, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Alexandria, La.

fed only on psyllid galls, but always killed the gall makers while feeding. Some parasites of psyllids fed on the gall after consuming the insects.

One of the psyllid gall makers often incorporated itself in the larger gall of the other psyllid, a condition termed marginal gall. Parasites found in marginal galls were always the same as those found in the large galls, which is considered to be evidence that certain parasites were attracted not by host nymphs, but by the gall.

Some primary parasites were more abundant than the others. Those whose larvae immediately fed on gall makers were more successful than other primary parasites, whose larvae began feeding after a period of time.

One new genus and four new species are described and methods of statistical separation are given for two closely related parasites.

Introduction

This bulletin is a study of three ecologically associated gall makers and their natural enemies on hackberry (*Celtis occidentalis* Linnaeus). Most published studies of galls have been limited to a single gall maker and its parasites. However, when three gall makers such as those which formed the basis of this study comprise such a close ecological association in the leaves of a single tree, a thorough study of all of them must be made in order to understand the biology of any one of them.

The background afforded by such an approach is particularly needed when biological control is being considered, as in the case of forest pests where chemical control is undesirable or unfeasible. Especially in view of this consideration, the work was supported by a grant of an honorarium from the New York State Museum and Science Service.

The three gall makers involved in this study represent two taxonomic groups. The psyllid group is composed of *Pachypsylla celtidismamma* (Riley), which causes the formation of a nipple gall on the underside of the leaf, and *Pachypsylla celtidisvesicula* (Riley), which causes the formation of a blister gall that is equally developed on both sides of the leaf.[1] The other taxonomic group is composed of one dipterous species of the family Cecidomyiidae. This species, a member of the genus *Phytophaga,* causes the formation of a thorn gall by the downward growth of the leaf tissue on the lower side of the leaf.

The problem is simplified somewhat by limiting it to the Cayuga Valley in the vicinity of Ithaca, N.Y. This reduces the number of insects involved, since in other parts of the country other galls and different parasites occur.

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[1] A third psyllid, *Pachypsylla celtidisgemma* (Riley), which makes a bud gall, also occurs in the Cayuga Valley. However, it is very rare and was not discovered until after the first draft of this bulletin was written.

To facilitate identification, references, and comparisons, the bulletin is divided into three parts. Part I contains three subsections, one for each gall maker. Part II consists of subsections on the natural enemies of the three gall makers described in part 1, including keys, descriptions of one new genus, and four new species. Part III contains a discussion of the host specificity of the natural enemies and the abundance of gall makers and parasites, a statistical analysis to assist in the separation of two species, taxonomic notes, and notes on distribution of hackberry in the Cayuga Valley.

Part I - The Gall Makers

Pachypsylla celtidisvesicula (RILEY) 1890 (Hemiptera: Psyllidae)

Pachypsylla celtidisvesicula is the most common gall maker on hackberry in the Ithaca area, and is widely distributed throughout the Cayuga Valley. Over 600 galls have been found on a single leaf, although the average is about 25–50. The gall (figure 6A) is a small, blisterlike formation, about 1/100 the volume of nipple gall made by its sibling species, *P. celtidismamma.* However, the nymph of *P. celtidisvesicula* (figure 10) is about one third the size of *P. celtidismamma.*

P. celtidisvesicula often becomes a pest in the fall by gathering in tremendous numbers on window screens. There are numerous references to it in the literature after 1890. Smith and Taylor, 1953, summarize the known biology and add many observations of their own. Important aspects of the biology not covered in Smith and Taylor, 1953, are discussed in the following paragraphs.

The egg (figure 1) is glistening white with no superficial markings, and ovate with the widest portion nearer the stalked end. The end attached to the ovary bears a protuberance before the egg is laid, but after the egg is laid the opposite end also acquires a stalk that attaches the egg to the leaf. The young nymph emerges from the top of the egg, a process requiring about 5 minutes.

In spring, adult psyllids persist about as long as the leaf buds (figure 26). In early spring, at anthesis when the buds are just opening, they are covered with psyllids. There are up to 50 adults on buds at anthesis, whereas in late June, when buds become scarce, only one or two psyllids may be found on a bud. By early July, the few remaining buds outnumber the psyllids, and by the middle of July the psyllids are gone. The adults feed actively on leaves in spring, and die within 24 hours if removed from the leaves. They apparently do not feed in the fall.

Mating took place only when insects were in direct sunlight. In the laboratory, adults on leaves in glass vials were placed in skylight, sunlight, and darkness, but mating was observed only in bottles exposed to sunlight. Oviposition in the laboratory occurred from 18 to 36 hours after mating, and the adults died shortly thereafter.

Eggs were usually laid on lower surfaces of exposed leaves, or on both sides of leaves in expanding buds. Egg-laying activity was greatest at anthesis when large numbers of psyllids clustered on hackberry flowers and swelling leaf buds. At this time numerous eggs were found even on flowers and outside surfaces of buds. Eggs laid on leaves in the laboratory required 6 days to hatch. The eyes of the embryo turned red 1 day prior to emergence.

After hatching, first-instar nymphs crawled from the lower surface, where most of the eggs were laid, to the upper surface of the leaf. After a time they settled down and fed. This feeding caused leaf tissue to proliferate and gradually close over the nymph. As the nymph became larger, its cavity gradually increased in size.

Blister galls were about 0.4 mm. in diameter immediately after the nymphs were covered by leaf tissue, and about 2.0 mm. when the adult was ready to emerge.

Emergence of fifth-instar nymphs began about September 1, but the peak emergence was at leaf fall on about October 1. Premature emergence was induced by removing the leaf from the tree.

Nymphs escaped by cutting a longitudinal slit through the gall on the top of the leaf with the anal spines, and came out tail first. Ecdysis occurred immediately after the adult emerged.

In contrast, parasites become adults before leaving the gall, and used their mouthparts to cut a small circular hole in the gall. Adults usually made their exit through the top of the leaf, rarely from the bottom.

Table 1. Measurements of the stages of *Pachypsylla celtidisvesicula*

Stage	Egg	Nymphal Instar 1	2	3	4	5	5-marginal*	Male **	Female **
Statistic									
Mean (mm.)	0.30	0.30	0.54	0.63	1.11	1.44	2.38	2.15	2.38
Minimum	0.25	0.25	0.45	0.50	0.70	0.70	1.40	1.50	1.80
Maximum	0.35	0.40	0.70	0.90	1.70	2.00	3.00	2.50	2.70
s	0.02	0.04	0.05	0.09	0.19	0.26	0.57	0.22	0.23
n	50	30	30	30	30	30	24	30	30

* Marginal galls are made by *P. celtidisvesicula* nymphs that have been incorporated into nipple galls. They are discussed later in this section.

** Only reared adults used for measurements; about 3 percent of the adults of *P. celtidismamma* and *P. celtidisvesicula* collected in the field cannot be determined satisfactorily to species.

Nymphal instars of *P. celtidisvesicula* (figure 1) were easily separated by size, shape or body, areas of pigmentation, anal spines, number of antennal segments, size of wing-buds, number of segments in legs, and relative length of certain setae on the head and tarsi.

Greatest growth of nymphs occurred after the third and fifth instars (table 1).

Blister galls are abundant on *Celtis occidentalis,* but less common on *C. laevigata, C. tenuifolis,* and *C. reticulata*; they apparently occur throughout the range of these trees in America north of Mexico.

Pachypsylla celtidismamma (RILEY) 1876 (Hemiptera: Psyllidae)

Pachypsylla celtidismamma (Riley) forms a nipplelike growth (figure 3) on the underside of hackberry leaves. Under favorable conditions as many as 30 galls may be found on one leaf, but the average number of galls on infested leaves is about three. At Ithaca, the gall is more numerous at higher elevations around the Cayuga Valley. The nipple gall is not the most common leaf gall, but is the most conspicuous. For this reason there is more literature on this gall than on any other found on hackberry. The best summary of its biology is by Smith and Taylor (1953). Details not covered by them are discussed in the following paragraphs.

The literature on *P. celtidismamma* is extensive, and numerous combinations have been used for the name. A nearly complete list of citations is given by Tuthill, 1943. Riley (1876) described the species. His description contains a figure of the nymph and gall that is reproduced in Comstock's *Introduction to Entomology.*

The period of greatest growth of the nymph of *P. celtidismamma* (figure 2) occurs between the fourth- and fifth-instars (table 2), but the gall enlarges most rapidly when nymph is in the first instar (figure 28). Nymphs of *P. celtidismamma* hatched from eggs earlier, but development was slower than nymphs of *P. celtidisvesicula* (figures 26 and 27).

Nipple galls are recorded from *Celtis occidentalis, C. laevigata,* and *C. reticulata*; apparently the species is distributed throughout the range of these trees in America north of Mexico.

Table 2. Measurement of the stages of *Pachypsylla celtidismamma*

Stage	Egg	1	2	3	4	5	Male	Female
Statistic								
Mean (mm.)	0.38	0.36	0.66	1.06	1.54	3.38	3.54	3.50
Minimum	0.37	0.25	0.30	0.80	1.00	1.80	2.90	2.80
Maximum	0.40	0.45	0.86	1.20	2.00	4.00	3.90	4.10
s	0.11	0.06	0.12	0.09	0.26	0.49	0.33	0.41
n	9	30	30	30	30	30	14	18

The marginal gall

A marginal gall is a blister gall that has become incorporated into a nipple gall. Figure 3A shows what may be the formation of this type of gall where nymphs of *P. celtidisvesicula* sink into nipple galls during their early growth. Figure 3B shows a cross section of a mature nipple gall with a marginal gall on its side. Nymphs in marginal galls have significantly larger mean lengths (F = 34.14) than nymphs of normal blister galls. Nymphs in marginal galls may have a greater food supply, and are of special interest because their parasites are the same as those that attack *P. celtidismamma* (figure 32).

Marginal galls are common. Examination of 162 nipple galls from four localities in the Cayuga Valley gave results shown in table 3. Over half contained one or more marginal galls, but the number of marginal galls per nipple gall varied widely between localities. Previous workers explained the phenomenon by stating that nipple galls are polythalamous, which is a freak occurrence, if it occurs at all. This may account in part for the failure of previous workers to find satisfactory morphological differences between adults of the two species, since all specimens reared from nipple galls were called *P. celtidismamma.*

Table 3. Number of marginal galls per nipple gall

Number of marginal galls per nipple gall	0	1	2	3	4	5	6	7
Percent	43.8	20.4	22.8	6.2	2.5	2.5	0.6	1.2

Phytophaga sp. nr. *spiniformis* (Patton)
(Diptera: Cecidomyiidae)

About 18 species of Cecidomyiidae (all probably *Phytophaga*) attack the genus *Celtis* in North America. Felt (1940) lists eight, but many of his other names may be synonyms. Most species in the United States occur in the southern States. This is shown in table 4, which includes three localities extensively collected. Only the thorn gall occurs in all three localities.

Table 4. Number of species of cecidomyiid galls for three localities in the United States

Locality	Species occuring at locality	Number of species which do not occur in the other two areas
Ithaca, N.Y.	1	0
Columbus, Ohio	9	3
Austin, Tex.*	14	9

* Data from John Riemann (personal communication)

Unlike pachypsyllid galls, which occur only in North America, cecidomyiid galls on *Celtis spp.* are found in most parts of the world, and some may be closely related to the North American species. Specimens of these galls are often found in many herbaria. Professor K. Yasumatsu sent the writer galls from *Celtis siniensis* on the island of Honshu. One of these galls is identical in external appearance and position of attachment on the leaf to the spine gall at Columbus, Ohio. The other gall is similar in appearance and position of attachment to the winged gall which is found at Columbus, Ohio, and Austin, Tex. For a discussion of cecidomyiid galls on *Celtis occidentalis* at Columbus, Ohio, see Moser, 1954.

The thorn gall (figure 10F) is the most widespread gall on the North American hackberries. It has been collected on *C. occidentalis, C. laevigata,* and *C. reticulata*; further collections may extend its geographic distribution to the western States and its host range to *C. tenuifolia.* Although galls appear the same throughout the country, the species may be separated into three populations on the basis of the larval spatulas (figure 4D). H. F. Barnes and R. H. Foote (personal communications) think the differences may be enough to call the populations separate species. Galls of the Ithaca population were found at Ithaca, N.Y., and McKees Half Falls, Pa.; those of the Columbus population were collected at Columbus, Ohio, and Alexandria, La., and the third population is known only from the vicinity of Austin, Tex.

The nomenclature of the thorn gall is complex. C. V. Riley *in* Packard, 1890, described the gall (not the insect), but gave the description a number, not a name. Patton, 1897, gave the name *Cecidomyiaceltis spiniformis* to Riley's description, but failed to designate a type or type locality. Riley's material is in the U.S. National Museum.

The material is in six lots, each lot on a pin, and composed of several leaves with galls on each leaf. Most of the pins contain little or no data, but one pin has a label which reads 107L. This number refers to a Hopkins-number card that contains the following data: " Columbus, Texas; July 79. Mostly lower side but occasionally upper. Box 11/60." The author designates 107L to be lectotype of *Phytophaga spiniformis* (Patton).

From the foregoing discussion, the synonomy is as follows:

Phytophaga Spiniformis (Patton)
" No. 34 " Riley, *in* Packard, 1890:614.
Cecidomyia-celtis spiniformis Patton, 1807: 248.
Cecidomyia unguicola Beutenmuller, 1907: 388; Felt, 1911: 457; Wells, 1916: 269, XVII, Fig. 8, 8a; Felt, 1918: 124; 1925: 64; 1940: 231.
Cecidomyia spiniformis (Patton), Felt, 1911: 458; 1918: 124; 1925: 62; 1940: 231; Smith, 1953: 110.

In summary, the name of the Texas population is *P. spiniformis,* but populations from other areas of the country may be different species. Male genitalia of specimens from other locations must be compared with the Texas population before their taxonomic status is known.

Pitcher, 1955, working with *Thomasiniana* found that Dyar's law held good for the head-capsule width of that genus, and also that differences in the respiratory system, epidermal texture, and development of the sternal spatula enabled one clearly to distinguish the instars. The writer repeated his measurements as closely as possible for the larva of *Phytophaga* sp. (figure 4). When instars are compared, it is found that head-capsule and sternal spatula lengths overlap, but that body length does not. As in *Thomasiniana,* qualitative characters are the best taxonomic characters for quick identification. The results are summarized in table 5.

The thorn gall is attached to the leaf longer than any other cecidomyiid gall on hackberry with which the writer is familiar. Other species were not observed to last on the leaf more than 1 month. The thorn gall grows more slowly, and is present for at least 3 months. This presumably allows the gall to be attacked by more parasites (figure 30). The gall is almost always present on the lower surface of the leaf, although rarely it is on the upper surface. This is true for most cecidomyiid galls of hackberry.

Most growth of the thorn gall occurs when the larva is in its second instar (figure 30), as compared to the first instar for *Pachypsylla* *celtidismamma.* Galls reach a mean height of 2.7 mm. in the second larval instar, and gradually grow to 3.3 mm. as the larva reaches third instar. After feeding, the larva forms a cocoon, and the gall begins to dry. This drying causes the gall to shrink slightly, to about 3.1 mm., and drop from the leaf almost a month before leaf fall (figure 29). The galls of *Pachysylla* are not detachable and fall with the leaf.

Table 5. Comparative morphology of the larval instars of *Phytophaga* sp.

Character	Statistic	Instar I	 II	 III
Length of body (extended)	Mean	0.36	0.72	1.71
	Minimum	0.30	0.50	1.30
	Maximum	0.40	1.10	2.00
	s	0.05	0.17	0.22
	n	7	30	30
Diameter of head-capsule (mm.)	Mean	0.039	0.048	0.063
	Minimum	0.036	0.038	0.552
	Maximum	0.041	0.065	0.792
	s	0.002	0.005	0.006
	n	7	30	30
Length of sternal spatula (mm.)	Mean		0.064	0.072
	Minimum		0.050	0.060
	Maximum		0.072	0.089
	s		0.005	0.008
	n	7	30	30
Respiratory system		Meta-pneustic	Peri-pneustic	Peri-pneustic
Sternal spatula		Absent	Present	Present
Epidermis	Texture	Smooth	Smooth	Papillate
	Microspines	Present	Present	Absent
	Setae	None	Strong	Weak
Color of body		Translucent white	Translucent white	Milk white

Part II

Natural Enemies - Keys, Descriptions, and Biologies

This part is divided into two sections: A. natural enemies of the psyllid galls, and B. natural enemies of the cecidomyiid gall. Each section begins with a key to adults reared from, and larvae found inside the galls. Discussions of individual species follow the keys.

A difficulty that appeared early in the study was that 10 of the 19 natural enemies were undescribed species. Four of these species are here described for the first time. However, adults of some species were not reared, making descriptions impossible, and in other cases no specialist could be found to describe them.

A. Natural Enemies of Psyllid Gall Makers

The 14 natural enemies of psyllid gall makers were of four types: primary parasites, secondary parasites, parasites from the hackberry leaf miners complex, and gall feeders.

Primary parasites were most abundant and contributed greatly to mortality of psyllids. Abundance of the other three categories were infrequent to rare.

Keys to insects associated with galls of *Pachypsylla*

I. KEY TO THE ADULTS

1. Mouthparts piercing-sucking (*Pachypsylla*) *2*
1′. Mouthparts chewing or lapping *3*

2. Length of body seldom more than 2.5 mm.; aedeagus of male with blunt apex; ventral valve of female genital segment suddenly narrowed ventrally for apical third *Pachypsylla celtidisvesicula*

2′. Length of body seldom less than 3.0 mm.; aedeagus of male with a ventral hook; ventral valve of female genital segment evenly narrowed to apex *Pachypsylla celtidismamma*

3. Two wings .... *Parallelodiplosis acernea*

3′. Four wings 4

4. Front wings horny (weevil)..... *Conotrachelus buchanani*

4′. Front wings membranous (wasps).................. 5

5. Ovipositor-sheaths longer than thorax (*Torymus*)...... 6

5′. Ovipositor-sheaths shorter than thorax................ 7

6. Ovipositor-sheaths less than twice the length of thorax ($\bar{x} = 1.557$); hind tibia black (figure 15A) *Torymus vesiculus*

6′. Ovipositor-sheaths more than twice the length of thorax ($\bar{x} = 2.20$); hind tibia the same color as femur *Torymus pachypsyllae*

7. Tarsi four segmented.............................. 8

7′. Tarsi five segmented.............................. 10

8. Body black .... *Hypertetrastichus ithacus*

8′. Body yellow and/or green.......................... 9

9. Body yellow with metallic-green stripes... *Moserina maculata*

9′. Body metallic-green .... *Achrysocharis vesiculis*

10. Body shining black.................. *Eurytoma semivenae*

10′. Body metallic-green .... *Psyllaephagus pachypsyllae*

II. KEY TO MOST DISTINCTIVE IMMATURE STAGES

1. Pupa; inside fourth-instar "puparium" of *Pachypsylla* (figure 10C) .... *Psyllaephagus pachypsyllae*

1′. Larva, external 2

2. Body yellow .... *Parallelodiplosis acernea*

2′. Body white 3

3. Body glabrous 4

3′. Body hairy 6

4. Body terete, much longer than wide; conspicuous "humps" present on dorsal surface (figure 10A) *Hypertetrastichus ithacus*

4′. Body oval; dorsal surface smooth, no more irregular than lower surface 5

5. Mandibles prominent; the remains of *P. celtidisvesicula* fifth-instar nymph in gall; cavity of gall full of whitish

brown pellets; blister gall only (figure 10D) *Achrysocharis vesiculis*

5′. Mandibles difficult to see; first-, second-, or third-instar remains of *Pachypsylla* nymph inside gall; gall clean (figure 10A) .... *Moserina maculata*

6. Head distinctly sclerotized and separate from body; mouthparts somewhat reduced but present; eyes present; nipple gall only .... *Conotrachelus buchanani*

6′. Head ill defined and about the same color as the body; mouthparts reduced to two sharp opposable mandibles; eyes absent 7

7. Head not sunken into body; dorsal aspect when viewed from the front appearing flat with a V-shaped notch, thus presenting a heart-shaped appearance; only one row of sensory setae per segment; humps on back prominent when body extended (figure 22D) .... *Eurytoma semivenae*

7′. Posterior part of head sunken into body, ill defined, dorsal aspect when viewed from the front is round; at least on the prothoracic segment several rows of sensory setae of various lengths; humps on back never prominent............ 8

8. Body never more than 1.5 mm. in length; at least abdominal segments 6, 7, 8, and 9 with one ill-defined row of setae (best seen when larva is cleared and mounted on slide); blister galls only (figures 14, 15B)...... *Torymus vesiculus*

8′. Body never less than 2.0 mm. in length; at least abdominal segments 6, 7, 8, and 9 with two ill-defined rows of setae; nipple galls only (figures 16, 22E).... *Torymus pachypsyllae*

Moserina maculata Delucchi 1962 (Hymenoptera: Eulophidae, Entedontinae)

Moserina maculata is a primary internal parasite of the first-, second-, and third-instar nymphs of *Pachypsylla celtidisvesicula* and *Pachypsylla celtidismamma.* It is the most common parasite, and attacks 60 percent of the nymphs of *P. celtidisvesicula.* Adults of the first generation emerge in spring from the previous year's fallen leaves about the time that leaf tissue starts to form around the first-instar nymphs. *Moserina* oviposits into nymphs in galls from the top of the leaf.

After feeding, larvae escaped from inside the nymphs. These larvae were small, shrunken, translucent, with large yellow guts. However, they soon increased about four times in volume and appeared turgid, fat, white opaque, and the gut could not be seen (figures 5, 6B). The two forms looked very different superficially, but when mounted on a slide and examined microscopically they appeared the same, except for size. This final growth was probably caused by the larva consuming gall tissue. Feeding was most evident in young nipple galls (figure 6B).

Only the large forms pupated. The prepupal stage lasted about 24 hours, and the pupal stage lasted about 9 days. Pupae turned black about 3 hours after pupation, except for the abdomen, which remained white and turned yellow about 2 days before emergence.

There was one complete generation during the summer, making a total of two generations per year (figure 31). After August 1, few adults were seen in the field and none by mid-August. Last instar larvae in galls went into an obligatory diapause, and did not pupate until refrigerated. Only large forms of larvae overwintered. These were almost twice as big as similar mature larvae from the preceding summer generation, probably because host nymphs and galls were larger.

Adults of both sexes walked in a dancelike motion, apparently moving farther sideways than forward. Adults of other chalcidoids in this study walked more or less in a straight line.

Nipple-gall forms (figure 6C) were much larger, but less common. Nipple galls are thicker and harder than blister galls, and *Moserina* may not have been able to penetrate them as easily with its ovipositor. A few larvae overwintered in nipple galls, especially in cavities of marginal galls which had thinner walls. Marginal galls were more accessible to *Moserina* than the more centrally located cavities of *Pachypsylla celtidismamma.*

M. maculata is a widespread species, collected from South Dakota, Minnesota, Kansas, Oklahoma, Texas, Arkansas, Tennessee, Ohio, West Virginia, Pennsylvania, New York, North Carolina, Georgia, and Louisiana.

Hypertetrastichus *New Genus*
(Hymenoptera: Eulophidae, Tetrastichinae

Diagnosis: The best character distinguishing the genus *Hypertetrastichus* from all other members of the subfamily Tetrastichinae of the family Eulophidae is the four-segmented funicle of the female antenna.

Type Species. Hypertetrastichus ithacus
Hypertetrastichus ithacus n. sp.

Quadrastichodella sp. Moser, 1956, J. Kans. Ent. Soc. 29(2): 57–62.
Quadrastichodella sp. Jensen, 1957, Hilgardia 27(2): 71–99.

Female. Figure 7. Length of body (tip of abdomen, not including ovipositor, to head inclusive) 0.8 to 1.50 mm.. ($\bar{x}$ = 1.15 mm., s = 0.16 mm., n = 55), all specimens measured in alcohol. Head and body black, shining; antennal scape black on basal half and yellow on apical half, pedicel and flagellum yellow; coxae and femora black, trochanter brown, tibiae and tarsi white with apical segment of each foretarsus brown.

Antennae inserted at ventral level of compound eyes, apices of scapes reaching two-thirds of the way from insertion to ventral margin of anterior ocellus; length of malar space five-ninths as great as height of compound eye; ocellocular line half as long as postocellar line. Mesoscutum four-fifths as long as wide and bearing two rows of bristles, each row with two bristles each of which are equidistant between the midline and lateral margin. Submarginal vein of forewing bearing two dorsal bristles; marginal vein four times as long as stigmal; median lengths of propodeum and postscutellum equal. Surface of propodeum smooth, median carina prominent, diameter of propodeal spiracle twice as great as width of space separating it from anterior propodeal margin; gaster 1.4 times larger than thorax and head combined; apex of ovipositor sheaths usually slightly exceeding apex of gaster.

Male. Unknown; the author believes it does not exist.

Type locality. Ithaca, N.Y.

Type depository. Female type deposited in the U.S. National Museum.

Range. Ithaca, N.Y., Columbus, Ohio, and Morgantown, W. Va.

Material examined. 55 female specimens from Ithaca, N.Y.

Biology. *H. ithacus* is an external obligatory parasite that parasitizes 9 percent of the *Moserina* population. No males have been found. It attacks the last-instar larva and pupa of the host. The first adult females apparently emerge about the same time as the *Moserina* adults, although in much fewer numbers. The larva (figures 8, 10A) does not enter diapause in midsummer like its host, but continues to attack *Moserina* until late fall. Length of a generation is about 1 month, but the exact number is obscure because the generations overlap in late summer and fall. It overwinters as a last instar larva inside blister galls and nipple galls. *H. ithacus* is much less common than its host, but there is a large emergence of adults about the first or second week in August. Adults can be easily collected at that time on the underside of the leaves where most of the oviposition takes place. Occasionally, adult females oviposit through to top of the leaf. The pupa remains white until about 36 hours before emergence, when it turns partially black. The pupa of *Moserina* turns black almost immediately after pupation; this affords a good character for the separation of the pupae of the two species.

Parallelopidiposis acernea Felt 1907[2] (Diptera: Cecidomyiidae)

This species is a fatal inquiline of both psyllids, and infests about 1 percent of galls. Oviposition begins by June 16, and continues until at least August 1. Eggs are laid parallel to leaf veins or perpendicular to side of gall (figure 10E). They usually occur singly, but three or four may be found together. First-instar larvae bore into galls and enter cavities with psyllid nymphs. As many as three young larvae were found in blister galls, and as many as 10 in nipple galls. However, never more than one survives to the final (third) instar.

Psyllid nymphs always die after larvae of *Parallelodiplosis* reach the third instar. Nymphs do not appear injured, and may die of starvation caused by competition for food. Apparently the larvae feed by sucking juices from galls. Most nymphs die in the fourth instar, but some in the third and fifth instars. Blister galls turn brown and dry soon after nymphs die. It appears then, that the inquiline must allow gall maker to remain alive until larva ceases feeding. Otherwise gall would die and cut off food supply of inquiline. Larvae overwinter inside galls.

Similar larvae were collected from psyllid and cecidomyiid galls at Columbus, Ohio, Raleigh, N.C., and St. Paul, Minn. They probably represent several species, and some form cocoons inside galls in the fall.

The three instars (figure 9) can be easily separated by qualitative and quantitative characters summarized in table 6. Due to scarcity of material, figures are not based on large numbers.

Leptacis sp. (Hymenoptera: Platygasteridae)

One female was observed June 16, 1957, ovipositing in eggs of *Parallelodiplosis acernea*. Specimen is deposited at U.S. National Museum.

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[2] G. Steyskal and A. Stone (U.S. Nat. Mus.) report that reared adults agree with types of *P. acernea* Felt 1907, N.Y. State Mus. Bull. 110 (22d Rep. State Ent. for 1906) : 143. Felt's types are from soft maple, but other specimens at the Museum were collected from deformed chokeberry fruit at Stow, Mass.

Table 6. Comparative morphology of the larval instars of *Parallelodiplosis acernea*

Character	Statistic	Egg	I	II	III
Body length extended (mm.)	Mean	0.39	0.54	1.09	2.09
	Minimum	0.35	0.35	0.90	1.60
	Maximum	0.40	0.60	1.40	2.50
	s	0.02	0.09	0.19	0.29
	n	8	7	5	13
Head capsule (mm.)	Mean		0.027	0.037	0.050
	Minimum		0.024	0.036	—
	Maximum		0.031	0.038	—
	s		0.003	0.001	—
	n		7	5	1
Sternal spatula length (mm.)	Mean		None	None	0.137
	n		7	5	1
Respiratory system			Meta-pneustic	Peri-pneustic	Peri-pneustic
Sternal spatula			Pseudo-spatula	Absent	Present
Epidermis	Texture		Smooth	Smooth	Papillate
	Microspines		None	None	None
	Setae		Weak	Strong	Strong
Body color			Yellow	Yellow	Yellow

Psyllaephagus pachypsyllae (Howard) 1885

The genus *Psyllaephagus* contains 11 described species; four from North America and two from Europe. All are parasites of family Psyllidae. *P. pachypsyllae* was designated as type of genus by Ashmead in 1900. Walton (1960) noted abundance of *P. pachypsyllae* around New York City, and established that it attacks the fourth-instar nymph. Moser (1956) states that it attacks all hackberry psyllids north of Mexico.

At Ithaca, *P. pachypsyllae* was the first parasite adult seen in field (May 9, 1957), and attacked first-instar nymphs of both psyllids before they formed galls. During oviposition, psyllid nymphs were often lifted off the leaf with sting, moved about, and otherwise roughly handled — but with no ill effects. Nymphs live normal life until the fourth instar (sometimes fifth) when the parasite larvae suddenly mushrooms in size (figure 10C). Nymphs swell to about three times their normal size, but remain alive until the larva reaches full size; only the essential organs remain unconsumed inside nymph. The parasite then defecates and pupates inside nymph which dies, and turns from a milk-white to a dark-brown color. The pupa soon turns black and overwinters inside host skin in gall. Diapause is obligatory, but adult will emerge in 14 days if pupa is refrigerated for 90 days at 6° C. Other parasites attack psyllids before they reach the fourth-instar, and many dormant larvae of *P. pachypsyllae* inside nymphs may be killed. Pupae of *P. pachypsyllae* were collected from 4 percent of nymphs in fall.

Specimens of *P. pachypsyllae* are recorded from Idaho, Colorado, New Mexico, Utah, Texas, Kansas, Minnesota, Arkansas, Louisiana, Tennessee, Ohio, New York, Pennsylvania, North and South Carolina.

Achrysocharis vesiculis n. sp. (Hymenoptera: Eulophidae)

(All measurements made from dried specimens)

Female. (figures 11, 13). Length of body (tip of abdomen, not including ovipositor sheathes, to head, inclusive) 1.0 — 1.6 mm., $\bar{x} = 1.4$ mm., $s = 0.18$ mm., $n = 14$. Antennae inserted dorsal of ventral margins of compound eyes but ventral of center of frons, apex of scape reaching dorsal margin of anterior ocellus, scape white on side next to head but dark on outside surface, giving antennae dark appearance; antennal formula 11123, basal part of first funical segment broken; height of compound eye three times as long as malar space, lower half of eyes clothed with *very* short hairs; postocellar line twice as long as ocellocular line; mandibles with two teeth; maximum width of mesopraescutum 1.3 times wider than long, one bristle present at each lateral margin halfway between cephalic and caudal ends of sclerite, surface of mesopraescutum, scutellum, metanotum and *propodeum* heavily reticulated; submarginal vein of forewing with two dorsal bristles, marginal vein six times as long as stigmal, infuscation of front wing light, heaviest around stigma and becoming obscure about midway to lower edge of wing; apex of hind wing pointed; fringe at posterior margin one-third as wide as wing at hamuli; mesoscutellum bearing one bristle on each side; proximal one-fourth of hind tibia dark; propodeum as heavily reticulated as scutellum, paraspiracular carinae absent, medial length of propodeum one-third as long as median length of mesoscutellum; gaster boat-shaped, slightly longer than head and alitrunk combined, maximum width of abdomen slightly wider than thorax, gaster clothed with short pubescence except on dorsum of first, second, and third segments, dorsum alternately shagreened and polished at each segment except first, second, and third segments; gaster pointed at apex and sheaths of ovipositor slightly produced.

Six specimens examined from Austin, Tex., appear the same as those from Ithaca, N.Y. Length of five specimens = 1.6 mm., and one = 1.9 mm.

Male. (figures 12, 13). Characters same as female except: length of two specimens 0.9 and 1.3 mm. Height of compound eye six times as long as malar space, no hairs on lower half of compound eyes; marginal vein five times as long as stigmal, infuscation of front wing very light, not heavy around stigma and extending at most to an imaginary line halfway to lower edge of wing; fringe at posterior margin of hind wing one-half as wide as wing at hamuli; proximal one-fourth of hind tibia dark on some specimens but light in others; gaster flat and almost as long as head and alitrunk combined; maximum widths of gaster and thorax about equal; white spot on gaster rather obscure and on caudal one-sixth of the first segment and cephalic half of second segment, remainder of gaster shagreened.

Two specimens examined from Austin, Tex., appear the same except for larger size (1.2 and 1.3 mm.); bodies not distorted upon drying like specimens from Ithaca, N.Y., proximal one-fourth of hind tibia white.

Type locality. Ithaca, N.Y.

Type depository. Female type deposited in the U.S. National Museum, Washington, D.C.

Range. Ithaca, N.Y.; Austin, Tex.

Material examined. 24 females and 7 males from Ithaca, N.Y.; 6 females and 2 males from Austin, Tex.

Part III contains a discussion of the taxonomic status of the species.

Biology. *Achrysocharis vesiculis* is a common, primary, internal parasite of fifth-instar (rarely fourth) nymphs of *Pachypsylla celtidisvesicula*. It parasitized 12 percent of nymphs in the Cayuga Valley, but only 1 to 7 percent on slopes of valley.

A few immature larvae were found inside nymphs of *P. celtidisvesicula* and large numbers of adults were observed ovipositing in galls by August 26; oviposition always was under leaf. No adults were observed in the field after September 14. Wings of the female were not held erect during oviposition like those of *Achrysocharis spiniformis*.

The larva of this species is similar to *Achrysocharis spiniformis* (figure 23). The last-instar larva (figure 10D) emerges from the nymph, eats all of the host skin except the tail, and overwinters as a larva in gall. The pupa of *A. vesiculis* darkens within 1 day after pupation.

A. vesiculis and *A. spiniformis* adults are similar in appearance, and Part III contains a key for their separation.

Torymus vesiculus Moser 1956 (Hymenoptera: Torymidae)

Torymus vesiculis is a common, external parasite of the fourth- and fifth-instar (rarely the third) nymphs of *Pachypsylla celtidis-vesicula.* It parasitizes 16 — 24 percent of nymphs at lower elevations, but practically none on slopes of Cayuga Valley, although host is abundant at both locations.

Oviposition takes about ½ hour. Nymph is stung and paralyzed and egg is laid beside the host. *T. vesiculus* almost always oviposits on the underside of the leaf, but the author observed it ovipositing once on top of the leaf. During oviposition the female is attached firmly to the gall. If the body is pulled, the thorax will separate from abdomen before the ovipositor detaches.

The immature larva sucks contents from nymph and then eats the skin except the tail. Nympal instar attacked can be determined by counting number of spines on tail.

The pupal period lasts about 2 weeks, and adult emerges inside the gall. The adult (figure 15A) cuts a circular hole in the top of the leaf and escapes. Emergence holes of *T. vesiculus* can be readily distinguished from the more numerous holes of *Moserina. T. vesiculus* holes average 0.5 mm. in diameter, whereas those of *Moserina* average 0.3 mm.

Males and females emerge at the same time and in about the same numbers. Males are rarely seen on leaves as are females. Instead, they usually " flit " in groups at tips of the leaves. Mating was not observed.

There are two generations per year at Ithaca. The first (summer) generation attacks the third-, fourth-, and possibly the early fifth-instar nymph. Second generation adults attack fifth-instar nymphs starting about September 5. Some of the first generation and all of the second generation overwinter as mature larvae in galls. The larva (figures 14B, 15B) will pupate without refrigeration.

Apparently *T. vesiculus* will attack *Pachypsylla celtidismamma* in special instances, although none was observed at Ithaca. The writer has one such record for Columbus, Ohio, and one for Nyack, N.Y.

Moser (1956) gives an account of the biology of this species at Columbus, Ohio. *T. vesiculus* is widespread, and has been collected in Idaho, Colorado, Texas, Minnesota, Ohio, New York, Massachusetts, West Virginia, North Carolina, and Georgia.

Torymus pachypsyllae (Ashmead) 1888 (Hymenoptera: Torymidae)

Although the name of this species is almost 70 years old, nothing has been published on its biology, and the name is often missing from taxonomic works (e.g. Huber, 1927).

Torymus pachypsyllae is closely related to *Torymus vesiculus* and the biology of their immature stages is similar. Unlike *T. vesiculus,* which is rarely found above the floor of the Cayuga Valley, *T. pachypsyllae* is common at all elevations, and was present in 25 percent of the nipple galls. Morphological differences between *T. vesiculus* and *T. pachypsyllae* are discussed in the appendix.

Fifth-instar larvae of *T. vesiculus* are less susceptible to disease in the laboratory. When larvae of both species are placed in stender dishes containing wet peat moss at room temperature, larvae of *T. vesiculus* are unaffected, while those of *T. pachypsyllae* (figures 16, 22E are attacked by fungus. However, larvae of *T. pachypsyllae* survive (figure 17) if only a trace of water is added to the peat moss.

T. pachypsyllae is recorded from Colorado, New Mexico, Ohio, New York, West Virginia, Pennsylvania, and North Carolina.

Eurytoma semivenae Bugbee 1957 (Hymenoptera: Eurytomidae)

Eurytoma semivenae was one of four new species described by Bugbee, 1957, from galls on hackberry. At Ithaca, it was usually found in nipple galls, although Bugbee, 1957, showed that it was common in blister galls on *Celtis laevigata* and *C. reticulata. E. semivenae* apparently fed on any inhabitant of galls, but occurred in less than 1 percent of galls.

Hosts were stung and paralyzed. Eggs were distinguished from those of other chalcidoid larvae by their black color (figures 18A, 22C). Usually one, but as many as three eggs were found in galls, but never more than one larva. Presence of several hatched eggs with larva indicated cannibalism.

The larva is similar in shape, color, and size to *Torymus pachypsyllae,* but distinguished by the heart-shaped head, sparse setae, and "humps" on dorsal surface. The larva feeds similar to that of *T. pachypsyllae,* first sucking contents of host, and then eating skin. The skin is not eaten until the larva reaches the fourth- or fifth-instar. After consuming the host, the larva feeds on the inner wall of gall, a phytophagous habit fairly common for the genus. Larvae occasionally break into marginal galls and consume inhabitants. Larvae were usually found feeding on paralyzed, fifth-instar larvae of *Torymus pachypsyllae.* In one instance a larva in a blister gall was seen feeding on an immature larva of *Achrysocharis vesiculis,* which was still inside the host nymph. Larvae occasionally break into marginal galls inside the host nymph. Larvae in rearing dishes commonly consumed other parasite larvae, indicating that although hosts are stung in nature, larvae may be able to feed on hosts that somehow escape stinging.

A whitish-brown material (figure 22D) is always found in the gall with the larva. A murexide test made on the material by Dr. R. L. Patton gave a red color, which showed a purine base, probably uric acid. The material may be excreted through the integument when the larva molts. Similar substances are recorded for other species of *Eurytoma,* and were also seen with *Achrysocharis vesiculis* (figure 10D).

E. semivenae has a summer and a winter generation at Ithaca, N.Y. Larvae of the latter overwinter in galls, but eggs of summer generation do not appear in galls until July. Specimens are known from Idaho, Colorado, New Mexico, Texas, Oklahoma, Kansas, South Carolina, North Carolina, West Virginia, Ohio, and New York.

***Conotrachelus buchanani* Schoof 1942**
(Coleoptera: Curculionidae)

Conotrachelus buchanani is an uncommon phytophagus weevil that feeds solely on tissue of nipple galls at Ithaca, but always kills the gall maker in the process. Larvae were found in 3 percent of the galls at most collecting localities.

According to Schoof (1942), *C. buchanani* is closely related to the plum curculio, *Conotrachelus nenuphar* (Herbst). He further states that the weevil is apparently restricted to *Celtis.*

The larva consumes the inside of the nipple gall and leaves a characteristic black frass. It kills the nymph in the gall, and soon the outside of the gall turns brown. After feeding, the mature larva drops to the ground, forms a cell in the soil, and pupates. Mature larvae formed cells and pupated in the laboratory when put on damp peat moss in a stender dish. Pupal period for one male was 19 days. Teneral adults require 3 days to color and 2 weeks for the scales on body to reach mature form. Recently emerged adults feed readily on the outside of nipple galls, making small deep circular pits with beak, but will die soon after food is removed. Dr. Donald Anderson compared genitalia of reared male with drawing of the type and found that they were alike.

There is one generation per year at Ithaca, the adult overwintering. Specimens of *C. buchanani* are recorded from Texas, Kansas, Iowa, Ohio, New York, and Pennsylvania.

Other parasites of *Pachypsylla* (Hymenoptera: Eulophidae)

Last instar larvae of *Sympiesis massasoit* Crawford 1913, *Sympiesis lexingtonensis* Girault 1917, and *Euderus* sp. were each found once in nipple galls. All were reared to adults. They are parasites of the two *Lithocolletis* leaf miners that commonly occur on hackberry in late summer and fall.

An internal parasite of *Torymus vesiculus* was collected twice, once from a fifth-instar larva and once from a pupa. Both collections were made on September 7, 1957. Attempts at rearing failed, but the larva appeared to belong to the family Eulophidae.

B. Natural enemies of cecidomyiid gall maker

Natural enemies of *Phytophaga* sp. were less diverse in habits and fewer in number than those of psyllids. A species of *Achrysocharis* was the only parasite closely related to a parasite of psyllids.

Keys to insects associated with *Phytophaga* sp.

I. KEY TO THE ADULTS

1. Wings vestigial .... *Eupelmella vesicularis*
1′. Wings present 2

2. Two wings . . . . *Phytophaga* sp.
2′. Four wings *3*
3. Wing veins completely absent . . . . *Trichacis* sp.
3′. Wing veins present along upper margin of wings *4*
4. Ovipositor exserted, as long as thorax . . . . . *Torymus diabolus*
4′. Ovipositor not exserted *5*
5. Thorax dull brown or black . . . . *Tetrastichus nebraskensis*
5′. Thorax metallic green . . . . *Achrysocharis spiniformis*

II. KEY TO THE MOST DISTINCTIVE IMMATURE STAGES

1. Mouthparts styletlike, parallel; spatula present on body; the gall maker. Figure 4 . . . . *Phytophaga* sp.
1′. Mouthparts biting, with definite mandibles that cross; spatula absent *2*
2. Body with numerous setae *3*
2′. Body without setae, glabrous *4*
3. Remains of egg as shown in figure 22B present *Torymus diabolus*
3′. Remains of egg not as shown in figure 22B *Eupelmella vesicularis*
4. Larva inside host *5*
4′. Larva outside host *6*
5. Body of unusual form, mostly composed of a "cephalothorax"; "tail" deeply forked; mandibles one third as long as body. Figure 19A . . . . First-instar *Trichacis* sp.
5′. Head and mandibles normal, composing less than one tenth of body length . . . . Immature *Achrysocharis spiniformis*
6. Body oval, more than half as wide as long; prominent "collar" on prothorax; body when put on slide and cleared has spiracles reduced. Figure 23A, B Last-instar *Achrysocharis spiniformis*
6′. Body cigar-shaped, less than half as wide as long; collar absent; spiracles large and prominent when larvae put on slide and examined under the compound microscope *Tetrastichus nebraskensis*

Trichacis sp.
(Hymenoptera: Platygasteridae)

Trichacis sp. is a primary, internal parasite of the larva of *Phytophaga* sp. It has one generation per year. First-instar larvae (figure 19) were found inside second- and third-instar larvae of *Phyto-*

phaga sp. by June 18. One mature *Trichacis* larva and three white pupae were collected August 5, 1957. By August 5, 1957, 90 percent of the *Phytophaga* larvae had stopped feeding and had formed cocoons, and larvae and pupae of *Trichacis* suddenly appeared. This suggests that termination of feeding by the host may cause *Trichacis* to begin larval development. By mid-September, diapausing, winged adults were found within host skins where they overwintered. Adults became active only after refrigeration at 6° C. for 90 days. Some first-instar larvae were also found in fall.

The only extensive study of *Trichacis* is by Marchal, 1906, who reported the following facts about *Trichacis remulus* Walker: (1) it is monembryonic (*Platygaster* and other closely related genera are often polyembryonic); (2) it oviposits in egg or first-instar larva; (3) the first-instar larva encysts in the posterior part of the nerve cord of the host until resumption of development.

Specimens of *Trichacis* were collected from Texas, Ohio, New York, and Pennsylvania.

Torymus diabolus n. sp.
(Hymenoptera: Torymidae)

This description is based on a single specimen reared from *Phytophaga* sp. at Ithaca, N.Y., collected August 20, 1957. The larva was extracted from the thorn gall, and refrigerated at 4° C. for 140 days. It transformed into a pupa after being warmed to room temperature; pupal period lasted 13 days. Adult emerged February 5, 1958, and lived 3 days in a vial with sugar water. Measurements are from a dried specimen.

Female (figure 20). Length of body 1.4 mm. (tip of abdomen, not including ovipositor, to head, inclusive), length of ovipositor sheathes 0.8 mm.; head metallic green, slightly longer than wide and clothed with suberect white hairs, carina around eyes extended at upper lateral corners into points giving distinct "horned" appearance; antennal formula 11173, antennae inserted just above level of ventral margin of compound eyes, apex of scape just reaching anterior ocellus, scape yellow except for apical one-fourth which is dark brown like remainder of the antennae, first funicle segment smallest and funicle segments gradually increasing in size to last segment (next to club) which is largest, pedicel slightly longer than last funicle segment; height of compound eyes three times as high as malar space; ocellocular line four-sevenths as long as postocellar line; maximum width of mesopraescutum 1.1 times wider than long, parapsidal grooves weak; maximum width of scutellum 1.1 times wider than long, cross-furrow absent; propodeum shagreened like rest of alitrunk, paraspiracular carinae absent, propodeum one-third as long as scutellum; submarginal vein of forewing with 11 bristles, marginal vein five times as long as submarginal, apex of hind wing rounded, fringe at posterior margin one-seventh as wide as wing at hamuli; tarsi of all legs white with last segment dark, coxae, femora and tibia of front legs tan, middle legs brownish-tan and hind legs brown; abdomen as long as alitrunk, maximum width of abdomen shorter than thorax, length of ovipositor longer than thorax but shorter than head and thorax combined.

Male. Not reared

Biology. This external primary parasite has only one generation per year. The author has never observed oviposition at Ithaca, N.Y., but a female was seen ovipositing at the base of a thorn gall on May 31, 1954, at Columbus, Ohio.

Unlike the torymid parasites of psyllids, which sting host and lay egg free in galls, *T. diabolus* does not sting host and suspends egg (figure 22B). About a week later, larva hatches (figure 21A) and usually fastens to the host larva. However, feeding does not begin until host larva reaches third-instar, and is sufficiently large to support the parasite. Many parasite larvae started to develop by late July, but some first-instar larvae were still seen in galls by late August. Once the first-instar larva starts feeding, it develops to a mature larva in about 1 week.

The last-instar larva (figure 21C, D) overwinters inside the gall on the ground. One adult female reared at Columbus, Ohio, lived 53 days in captivity in a vial with sugar water as food.

First-instar larvae were found in about 23 percent of the galls, but last-instar larvae were found in only 1 percent or less, probably because of competition from *Achrysocharis spiniformis*. Occasionally, *Torymus* attacked *A. spiniformis*.

Achrysocharis spiniformis n. sp.
(Hymenoptera: Eulophidae)

All measurements made from dried specimens. Appendix 2 gives a discussion of the taxonomic status of this species.

Female (figure 24). Length of body (tip of abdomen, not including ovipositor sheaths, to head inclusive) 1.3 — 1.8 mm., $\overline{x}$ — 1.5 mm., s — 0.20 mm., n = 5. Antennae inserted dorsal of ventral margins of compound eyes but ventrad of center of frons, apex of scape reaching dorsal margin of anterior ocellus, scape white on basal half and dark on anterior half; antennal formula 11123, basal part of first funical segment broken; height of compound eye four and one-half times as long as malar space, lower one-half of eyes clothed with *very* short hairs; postocellar line twice as long as ocellocular line; mandibles with two teeth; maximum width of mesopraescutum 1.3 times wider than long, one bristle present at each lateral margin halfway between cephalic and caudal ends of sclerite, surface of mesopraescutum, scutellum and metanotum heavily reticulated; submarginal vein of forewing with two dorsal bristles, marginal vein seven times as long as stigmal, infuscation of front wing dark, heaviest around stigma and extending down to lower edges of wing; apex of hind wing pointed, fringe at posterior margin one-sixth as wide as wing at hamuli; mesoscutellum bearing one bristle on each side; hind femora white; surface of propodeum much more lightly reticulated than scutellum, appearing almost smooth, paraspiracular carinae absent, median length of propodeum one-fourth as long as median length of mesoscutellum; gaster boat-shaped, slightly longer than head and alitrunk combined, maximum widths of thorax and gaster equal, gaster clothed with short silvery pubescence, dorsum alternately shagreened and polished at each segment, the shagreened parts becoming more polished at the cephalic end, gaster pointed at apex and sheaths of ovipositor slightly produced.

Four specimens from Columbus, Ohio, appear the same except that average size is larger ($\bar{x} = 1.7$ mm.), and bodies do not distort upon drying like specimens from Ithaca, N.Y.

Male (figure 25). Characters the same as female except: length 0.7 — 1.1 mm., $\bar{x} = 0.89$ mm., $s = 0.13$ mm., $n = 9$. Antenna with scape darkened entire length except for white strip on inside basal one-half, basal part of first funicle segment not broken; lower one-half of eyes without short hairs; marginal vein of front wing six times as long as stigmal vein, infuscation heaviest around stigma but extending slightly past an imaginary line one-half way to lower edge of wing; fringe at lower margin of hind wing one-half as wide as wing at hamuli; gaster flat, almost as long, or as long, as head and alitrunk combined, thorax slightly wider than gaster, cephalic one-third of gaster with an almost transparent white spot, caudal two-thirds of gaster shagreened.

Three specimens from Columbus, Ohio, appear the same except for larger average body size $\bar{x} = 1.2$ mm.

Type locality. Ithaca, N.Y.

Type depository. Female type deposited in the U.S. National Museum, Washington, D.C.

Range. Ithaca, N.Y.; McKees Half Falls, Pa.; Columbus, Ohio; and Austin, Tex.

Material examined. 16 females and 61 males from Ithaca, N.Y.; four females and three males from Columbus, Ohio.

Biology. *Achrysocharis spiniformis* is a primary internal parasite that feeds on second- and third-instar larvae of *Phytophaga* sp. It is the most common parasite found in thorn galls, and exhibits 88 to 100 percent parasitism under favorable conditions.

On July 16, 1957, two ovipositing females were seen on the lower surface of a leaf on which 15 galls were present. Their search for galls was slow and deliberate, during which they frequently held their wings vertically. In this position the characteristic strips on the wings could easily be seen. When a gall was found, she mounted and examined it carefully with her antennae as she circled the gall repeatedly. Oviposition time lasted from 3 to 5 minutes, after which she either rested or began searching for more galls.

The host larva was always stung and paralyzed and remained fresh for about 10 days. Then the body contents rapidly began to dissolve into a liquescent mass, and were entirely consumed after 3 to 4 days. The larva then egressed and ate the skin. Second-instar larvae of *Phytophaga* that were stung always had a conspicuous oviposition-puncture, and usually an immature *A. spiniformis* larva inside. However, active, second-instar larvae were sometimes found with an oviposition-puncture, but without a larva of *A. spiniformis* inside, indicating that stinging alone may not cause paralysis. Many paralyzed, third-instar *Phytophaga* larvae with larvae of *A. spiniformis* inside were found without oviposition-punctures. This may mean that stung, second-instar, host larvae were able to moult into the third instar, after which the larva of the parasite developed. Active second- or third-instar larvae of *Phytophaga* without punctures never contained larvae of *A. spiniformis,* although frequently first-instar larvae of *Trichacis* were seen.

Achrysocharis will sting and lay eggs in host larvae even though other parasites are already present. Stung, liquescent larvae of *Phytophaga* were frequently found inside galls alongside a first-instar larva of *Torymus,* leaving the latter without a host.

Adults of *A. spiniformis* from overwintering galls were seen by July 16 when *Phytophaga* larvae were mostly in the second instar. A month or more may be required to complete the cycle from egg to adult in the summer. The pupal period lasts 14 to 15 days. The first (summer) generation began to escape from galls by August 3, in the laboratory. Parasite larvae extracted from galls after September 1 were presumably of the second summer generation. Larvae and pupae in the laboratory did not enter diapause.

Adults of both species of *Achrysocharis* may be found on the same hackberry leaf, and are separated by the key in Part III.

Tetrastichus nebraskensis (Girault) 1916 (Hymenoptera: Eulophidae)

T. nebraskensis attacks chiefly gall midges. Burks, 1943, and Guppy, 1956, reported it from the clover-seed midge and Judd, 1958, collected it at London, Ontario, from *Rhabdophaga* nr. *rhodoides* Walsh that makes galls on the sandbar willow. The writer has records of it from the thorn gall at Ithaca, N.Y.; McKees Half Falls, Pa.; and Columbus, Ohio; also from *Pachypsylla ?nmbilicus* Riley (large blister gall) at Dallas, Tex.

T. nebraskensis was rare in thorn galls at Ithaca, N.Y., but appeared to be much more common at McKees Half Falls, Pa., about 50 miles south of Ithaca.

One immature larva collected at Ithaca (July 16, 1956) was feeding on a larva of *Achrysocharis spiniformis,* but four immature larvae collected at McKees Half Falls August 15, 1957, were feeding on larvae of *Phytophaga* sp. Another larva of *Tetrastichus,* which had fed on a pupa of *A. spiniformis,* was also found at the latter locality. In summary, it seems that *T. nebraskensis, like Eurytoma semivenae,* feeds upon whatever happens to be in the gall. The largest emergence of *T. nebraskensis* appears to be at gall fall.

Eupelmella vesicularis (Retzius) 1783 (Hymenoptera: Eulophidae)

This species was seen only once, and may be classed as an " accidental " parasite. It was collected August 21, 1957, as an adult female still inside the gall, but active and ready to emerge. The specimen was very small (1.0 mm. in length), but Burks, 1957, (personal communication), was satisfied that it was *E. vesicularis,* although he stated that it must have been greatly undernourished. A normal specimen (2.5 mm. in length) was collected sweeping by Edward Menhinick September 1, 1957, at Beebe Lake on the Cornell campus.

E. vesicularis is one of the most versatile chalcidoid species known. It is recorded as a primary and secondary parasite of Diptera, Coleoptera, Hymenoptera, Lepidoptera, Homoptera, and Orthoptera.

Part III

Miscellaneous Notes on Life Histories and Interrelationships

Discussion

Host specificity of the natural enemies (figure 32). Although cecidomyiid and psyllid galls often occurred on the same leaf, no parasites of psyllid nymphs attacked cecidomyiid larvae or vice versa.

Natural enemies of psyllid nymphs were of four types: primary parasites, secondary parasites, parasites from the hackberry leaf miner complex, and gall feeders. Habits of the primary parasites were diverse. *Moserina maculata* and *Psyllaephagus pachypsyllae* were internal parasites. They attacked early-instar nymphs of both psyllids. *Torymus pachypsyllae, T. vesiculus,* and *Achrysocharis vesiculis* were external parasites of late-instar nymphs, and with one exception, fed only on one species of psyllid. Primary parasites of early-instar nymphs were either attracted to exposed nymphs, or attacked both psyllid galls indiscriminately. There is evidence that at least one primary parasite of late-instar was attracted by the gall. *Torymus pachypsyllae,* normally a parasite of late-instar nymphs, of *P. celtidismamma,* also attacked late-instar nymphs of *P. celtidisvesicula* when the latter produced marginal galls on nipple galls. Although *T. pachypsyllae* was never found in blister galls, its presence in marginal galls showed that its larvae were capable of developing on nymphs of *P. celtidisvesicula.* From this it is concluded that ovipositing females of *T. pachypsyllae* were attracted not by the host nymph, but by the gall. Other primary parasites of late-instar nymphs may be attracted in a similar manner. Four species of secondary parasites were found in psyllid galls. *Eurytoma semivenae* usually attacked primary parasites, but occasionally fed on psyllid nymphs. The other three apparently attacked only primary parasites.

Conotrachelus buchanani and *Parallelodiplosis acernea* fed only on galls, but always killed the psyllid nymph in the process. The former ate only nipple galls, but the latter was found inside both psyllid galls. Certain primary and secondary parasites consumed tissue inside galls after devouring the host. In fact, *Moserina* larvae apparently would not pupate until they had fed on gall tissue. *Eurytoma* larvae usually ate gall tissue, and it was suspected that larvae of *Torymus pachypsyllae* and *Achrysocharis vesiculis* fed similarly.

Three parasites of the hackberry lepidopterous leaf miner complex were found once each in nipple galls.

Three primary parasites, two external and one internal, attacked *Phytophaga* larvae in thorn galls. Two secondary parasites were found in galls, but both were general feeders, and not specific to the thorn gall complex.

Relative abundance of gall makers and parasites. It was obvious at the beginning of the study that some gall makers and parasites were more common than others. One objective of the study was to learn reasons for this. Blister galls outnumbered nipple and thorn galls 100:1 or more in the Cayuga Valley, although numbers of the three galls fluctuated greatly between localities. Parasite populations also differed between localities, and in some instances, the absence of a parasite in an area resulted in a high population of the gall maker. This was most apparent for the thorn gall. For instance, in one locality *Achrysocharis spiniformis* was never found. Correspondingly, thorn galls were abundant. Although the occurrence of low numbers of a parasite in an area was sometimes a reason for the abundance of a certain gall, it was not determined why blister galls outnumbered the other two galls. Parasites do not seem to be the answer, because blister gall nymphs were as heavily parasitized as the other two gall makers. Perhaps *P. celtidisvesicula* had a greater biological potential, or was better adapted to *Celtis occidentalis* than the other two species. At Alexandria, La., however, thorn galls on *Celtis laevigata* number about the same as at Ithaca, N.Y., but seem to outnumber blister galls which are uncommon. It appears, then, that *P. celtidisvesicula* does not thrive as well on *C. laevigata* as on *C. occidentalis,* and the abundance of a gall in any particular area of the country may depend greatly on how well it is adapted to the host tree.

Only certain of the primary parasites were common in galls. Other primary parasites, secondary parasites, parasites from lepidopterous leaf miner complexes, general parasites, and gall feeders were uncommon or rare.

Ability of the young larva to develop quickly seemed to favor the abundance of some primary parasites over others. For instance, *Achrysocharis spiniformis* was usually able to compete favorably with *Torymus diabolus* and *Trichacis* sp. because young larvae of *A. spiniformis* consumed the cecidomyiid larvae before the latter two came out of diapause (figure 29). Likewise, many young larvae of *Psyllaephagus* may not have been able to develop inside psyllid nymphs because other parasites ate the host first (figures 26 and 27).

The three parasites with delayed larval development, *Psyllaephagus, Torymus diabolus,* and *Trichacis* sp., were relatively large but, unlike other large parasites, they laid their eggs on or in very young host larvae or nymphs. Thus the young larvae had to delay feeding until the host was large enough to consume. In the meantime, however, the host was often eaten by another parasite.

Elevation affected the abundance and distribution of at least one parasite, *Torymus vesiculus.* This species was abundant in the bottom of the Cayuga Valley, but became rare above 50 feet on the sides of the valley, even though abundant host material was available. The closely related species, *T. pachypsyllae,* was common at all elevations.

Miscellaneous parasites such as those from leaf miner complexes and general parasites were probably not abundant because their life cycles were not synchronized with those of the gall makers. Although numerous secondary parasites were present, none greatly reduced numbers of the primary parasites.

In summary, primary parasites were the most abundant natural enemies, and competition between them seemed to affect numbers of individual species more than any other factor.

A method of separating *Torymus vesiculus* and *Torymus pachypsyllae* by means of the analysis of covariance

Specimens of *Torymus vesiculus* reared from blister galls differed from specimens of *Torymus pachypsyllae* reared from nipple galls in the following respects: (1) specimens reared from nipple galls were larger than those reared from blister galls, but the host of the nipple gall *Torymus* was correspondingly larger, (2) the relative length of the ovipositor when compared to the thorax was greater for *T. pachypsyllae* than for *T. vesiculus.*

The first observation is difficult to test, but the second was tested by the analysis of covariance according to Snedecor, 1956, (p. 395). The regression coefficient for *T. vesiculus* was 1.713 and for *T. pachypsyllae* was 1.940, but they were not found to be significant ($F = 0.5377$) when a test for the homogeneity of regression coefficients was made. When variances were pooled and compared, however, the difference was highly significant (F = 42.38**). The common mean for length of thorax was 0.896 mm., and the adjusted means for the length of the ovipositors were 1.48 mm. for *T. vesiculus* and 2.11 mm. for *T. pachypsyllae.*

Since F for the pooled variances was highly significant and the F value obtained from the test for the homogeneity of regression coefficients was not, the conclusion is that the regression lines do not explain the differences among the ovipositor lengths. After the ovipositor lengths were adjusted to a common thorax length, they still differed significantly. Evidently the degree of change of ovipositor length to thorax length between the two species is not the same.

It might be thought that the reason for the difference between the relative size of ovipositors of the two species is that the hosts are different species. This was ruled out because specimens of *T. pachypsyllae* reared from marginal galls had ovipositor lengths the same as those reared from nipple galls. It seems, therefore, that the species of host is not the primary cause of these differences in the morphology of the parasites.

Notes on the taxonomic status of *Achrysocharis vesiculus* and *A. spiniformis*

Before these two species were described, it had to be ascertained whether or not they actually belonged in the genus *Achrysocharis* which is a poorly known and difficult genus. B. D. Burks, U.S. Department of Agriculture (personal communication), stated that they belonged to the genus *Achrysocharis.* However, the European species *formosa* Westwood has been placed in *Achrysocharis,* and it was deemed best to see if the two proposed species were congeneric with the European representative. Consequently, a male and a female of *A. vesiculis* and *A. spiniformis* were sent to Dr. M. W. de V. Graham, Hope Department of Entomology, University Museum, Oxford, England. Dr. de V. Graham made a study of the problem and sent the following reply: " I was never quite satisfied about the identity of *Achrysocharis* Gir. and *Achrysocharella* Gir., so as your question was important, I took the opportunity of obtaining Girault's types of loan. These are *Achrysocharis bifasciata* and *Achrysocharella dubia,* the two type-species. Having seen these, I would say that both your species would best be placed in *Achrysocharis.* The only European species I know which fits into this genus is *lanassa* Walker (*Entedon lanassa* Walker, 1839, mon. Chaldiditum *1*) ; this is remarkably like your species, but has much finer sculpture on the mesoscutum and scutellum, and differs in other details. I would place *formosus* Westwood, and possibly *ruforum* Krausse (*Wolffiella ruforum*) in *Achrysocharella* Gir. *Achrysoscharis* and *Achrysocharella* are usually distinguished by the number of anelli (one in the former, two in the latter), but these are very hard to see well and one is not always sure of the number. I find a difference in the forewing which may be useful:

> *Achrysocharis* Gir. — Bare strip in front of stigma just below margin of wing which is more or less delimited below a line of hairs (this character can be seen in figures 11B, 12B, 24D, 25D).
> *Achrysocharella* Gir. — No bare strip or line of hairs (i.e., hairy throughout). Your two species have the bare strip; *Achrysocharella dubia*, and *formosus* Westwood have not."

Achrysocharis vesiculis and *A. spiniformis* are separated by the following key:

1. Ovipositor present; last abdominal sternite divided. Females *2*

1′. Ovipositor absent; white spot on second abdominal segment. Males *3*

2. Upper part of propodeum reticulated, resembling the scutellum; proximal one-fourth of hind tibia black; scutellum usually convex; wing infuscation (figure 11) extending not more than one-half across wing from stigma. . *A. vesiculis* Moser

2′. Upper part of propodeum smooth, not resembling reticulation of the scutellum; proximal one-fourth of hind tibia white; infuscation of wing (figure 24A) extending across wing from stigma. . . . . *A. spiniformis* Moser

3. Middle of propodeum flat or slightly rounded, not forming a ridge, sculpturing at middle resembling the scutellum; white spot on dorsum of abdomen small, nontransparent, located on the caudal one-sixth of the first segment and the cephalic one-half of the second segment. . . . . *A. vesiculis* Moser

3′. Middle of propodeum forming a ridge, not flat, sculpture weak, especially on the upper part giving a smooth and shiny appearance when compared to the deeply reticulated scutellum; white spot on dorsum of abdomen large, transparent enough to allow one to see completely through the abdomen; spot completely divides the second segment, caudal one-half of the first segment of cephalic one-half of the third segment . . . . *A. spiniformis* Moser

Distribution of *Celtis occidentalis* in the drainage of the Cayuga Lake Inlet

This species inhabits banks and streams along the sides of the Inlet valley, and the bases of the surrounding hills; isolated specimens are occasionally found in the areas between streams. It is rarely found in the valley proper below the 122-meter (400-foot) level, and rarely above the 155-meter (500-foot) level on the sides of the hills. The southern limit of its distribution in the Inlet valley is 3.2 kilometers southwest of bench mark 387 at the junction of Route 13 and Seven Mile Drive. Apparently the species is not found again in great numbers until one reaches the Susquehanna River in the vicinity of Williamsport, Pa. The author has not studied the region north of the south end of Cayuga Lake, but Wiegand and Eames, 1925, state that the species is found north along the Cayuga Lake shore.

Survey of Literature

Only general papers on galls of the hackberry are considered under this heading; papers pertaining to specific subjects are discussed at appropriate points. There is an extensive literature, consisting mostly of short notes, but it can be divided into several broad categories.

The descriptive literature is mostly by Riley, and most of it is contained in Riley, 1890. Patton, 1897, gave names to many cecidomyiid galls, described by Riley, and erected a genus for them (*Cecidomyia-celtis*).

A large category of literature consists of locality lists. It is extensive and typified by Beutenmuller's paper, 1892, entitled *Catalog of gall-producing insects found within fifty miles of New York City.* Other works include Mally, 1894; Cook, 1904; Jarvis, 1907; Smith, 1909; and Felt, 1940.

There are several good papers on the anatomy of the galls and gall makers. Cook, 1903, was the first to describe the anatomy of galls of the hackberry, and used the gall of *Pachypsylla celtidismamma.* However, he did not compare it with other galls on hackberry because he was primarily interested in comparing certain structures of galls made by the genus *Pachypsylla* to galls made by other genera occuring on other plants. Wells, 1916 and 1920, published two papers on the anatomy of galls. Detailed drawings of all the galls then known on hackberry are given, together with notes on their development. Stough, 1910, exhaustively dealt with the external morphology of the adult of *Pachypsylla celtidismamma.*

There are two catalogs and three revisionary works which deal with the North American Psyllidae. The catalogs are by Van Duzee (1917) and Aulmann (1913); the revisions are studies by Crawford (1914), Caldwell (1938), and Tuthill (1943).

Some information on the biology of the gall makers is found in almost every paper, but a great deal is repetitious. The best paper is the study of *Pachypsylla celtidisgemma* by Walton, 1960. There are no extensive works on the biology of hackberry Cecidomyiidae.

Literature on natural enemies has progressed little beyond the descriptive and listing stage, although two of the chalcid parasites were described over 70 years ago.

The best paper on the chemical control of gall makers on hackberry is by Smith and Taylor, 1953. *Pachypsylla celtidisvesicula* sometimes reaches the level of economic importance because it occurs in large numbers on window screens in the fall. *Pachypsylla venusta* and the hackberry " witches-broom " mite (*Eriophyes celtis*) are at times considered economic pests because they make hackberry trees unsightly. Smith used several types of the newer organic insecticides combined with various oils, but found that none was particularly successful. He also found that time of application was very important, and that the nymphs were almost impossible to kill after the galls had formed. Regarding biological control, Moser, 1956, states " the fact that the psyllids emerge in the fall and overwinter as adults, whereas their parasites overwinter as larvae or pupae in the galls, makes it a poor practice to rake and burn the leaves of this tree because this destroys the parasitoids."

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FIGURE 1

Pachypsylla celtidisvesicula, immature stages

A. First instar. Coloration of dorsal aspect. *P. celtidismamma* has no dorsal coloration.
B. Second instar
C. Third instar
D. Fourth instar
E. Fifth instar. Spines on tail are on dorsal aspect.
F. Shape of egg in ovary.
G. Shape of egg after it has been laid and attached to the leaf. Stalk at upper end is point of attachment to leaf. Stalk on lower end is point of attachment to ovary. Nymph emerges headfirst at lower end.

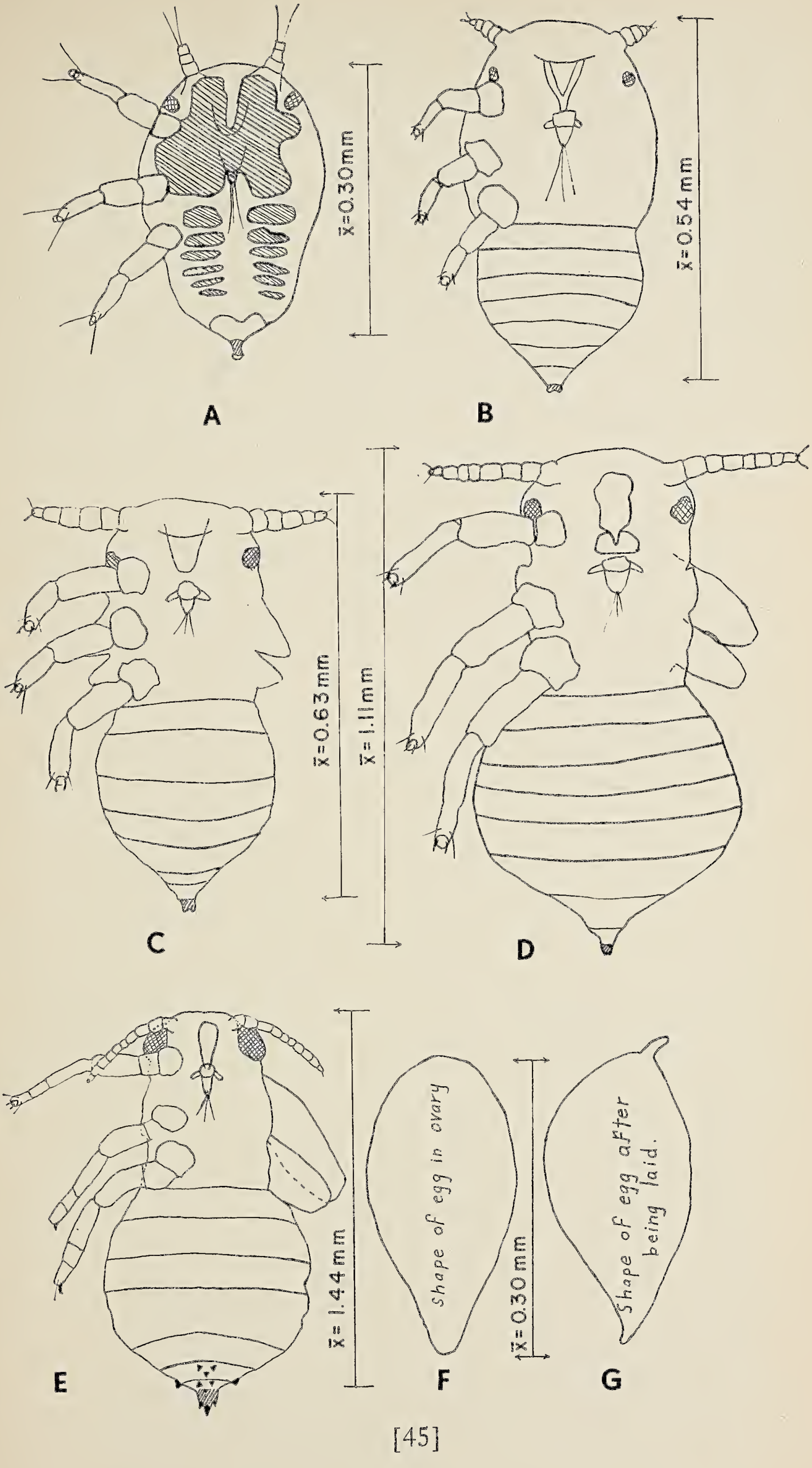

x̄=0.30 mm
A
x̄=0.54 mm
B
x̄=0.63 mm
x̄=1.11 mm
C
D
x̄=1.44 mm
E
Shape of egg in ovary
F
x̄=0.30 mm
Shape of egg after being laid.
G

FIGURE 2

Pachypsylla celtidismamma, immature stages

A. Shape of egg in ovary
B. Shape of egg after it has been laid
C. First-instar nymph
D. Second-instar nymph
E. Third-instar nymph
F. Fourth-instar nymph
G. Fifth-instar nymph

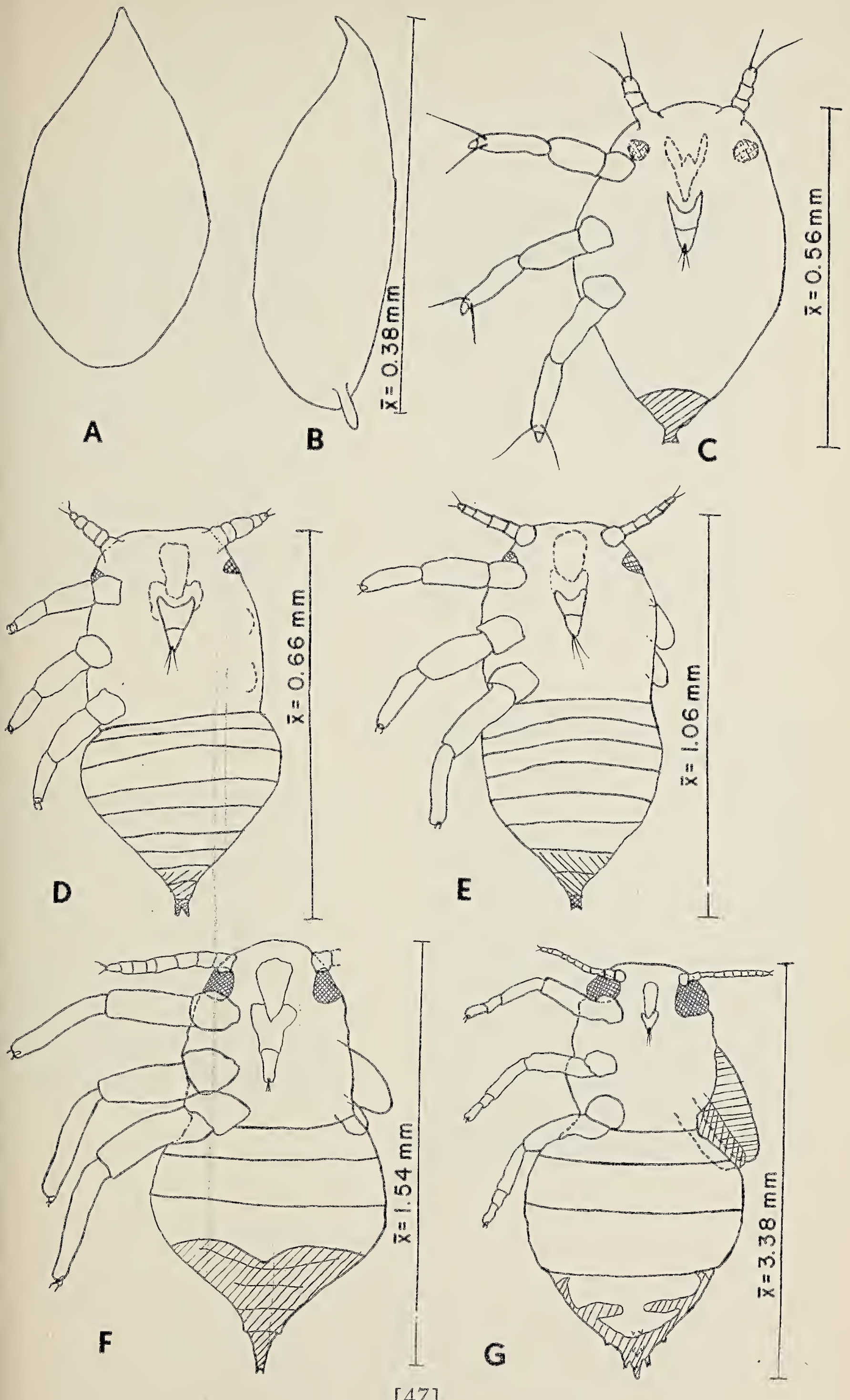
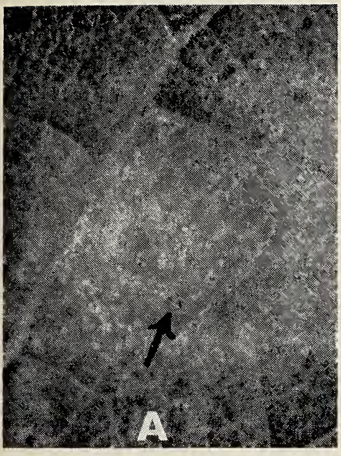
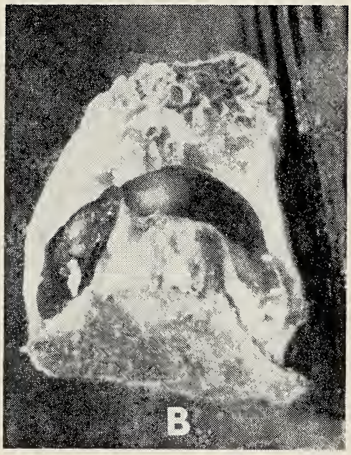

A
B
x̄ = 0.38 mm
C
x̄ = 0.56 mm
D
x̄ = 0.66 mm
E
x̄ = 1.06 mm
F
x̄ = 1.54 mm
G
x̄ = 3.38 mm

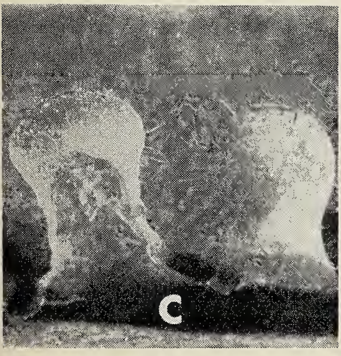
FIGURE 3

Nipple galls

A. First-instar nymph of *Pachypsylla celtidisvesicula* on young nipple gall. Nymph may produce marginal gall.
B. Nipple gall with marginal cavity at left.
C. Nipple gall containing second-instar nymph. Gall almost of mature height, but cavity still very small. Columbus, Ohio, population.
D. Nipple gall containing fifth-instar nymph.


A


B


C

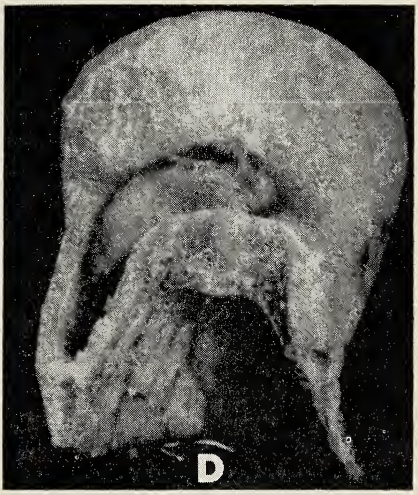

D

FIGURE 4

Phytophaga sp., larva

A. First-instar larva, side view with dorsal aspect at bottom. Microspines shown only on first abdominal segment. Head shows antenna and stylets.
B. Second instar, dorsal view (spatula on ventral aspect). Microspines shown only on third abdominal segment. Spiracle on third thoracic segment is vestigial.
C. Second instar, side view with dorsal aspect at bottom
D. Spatulas of third instar showing variations between Ithaca, N.Y.; Columbus, Ohio; and Austin, Tex.
E. Third instar. Dorsal view (spatula on ventral aspect). Papillate surface shown only on third abdominal segment. Spiracle on third thoracic segment poorly developed.
F. Third instar. Larva unextended as normally seen in gall.
G. Third instar. Side view with dorsal aspect down. Microspines not shown, setae shown only on first thoracic segment.
H. Third instar, ventral aspect showing details of spatula and head. Mean length = 0.20 mm., A — antenna, S — stylets.

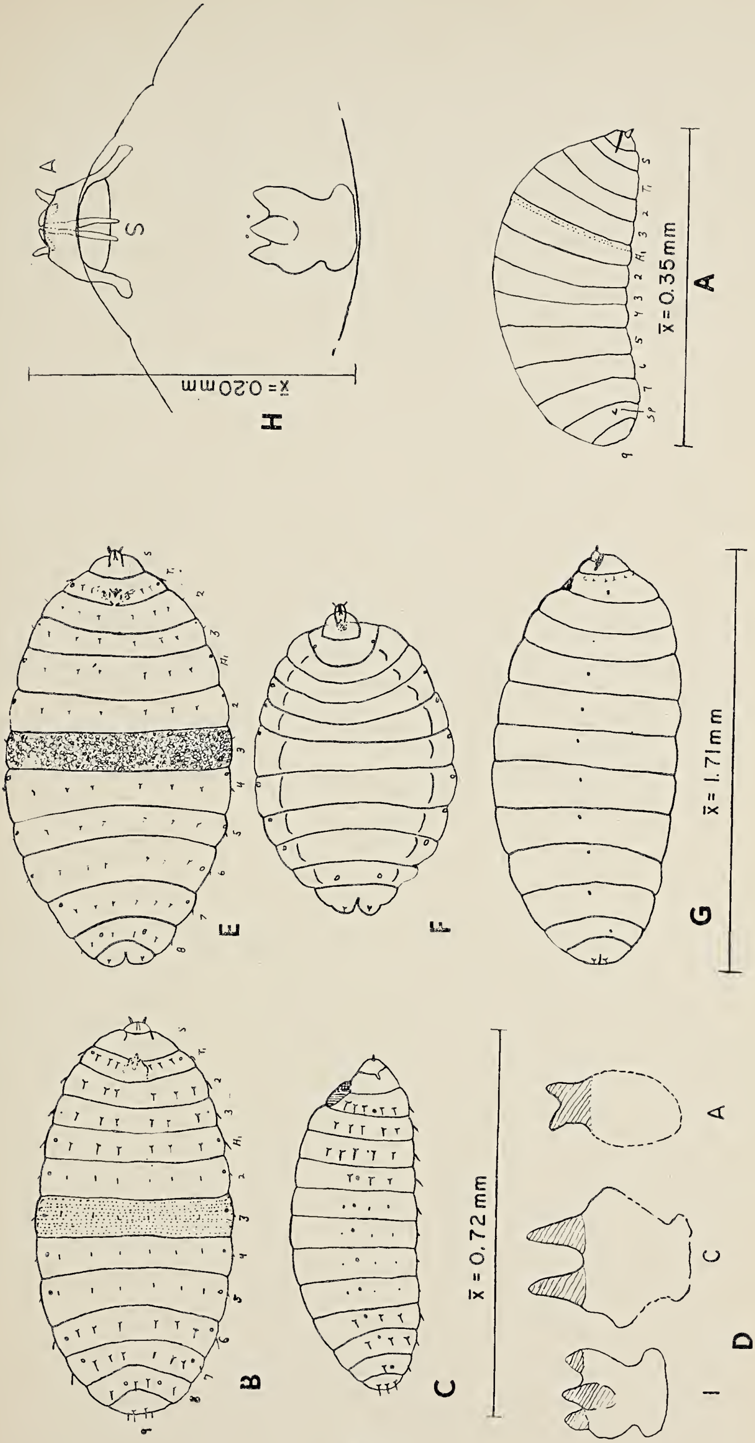

H
x̄ = 0.20 mm
A
S
A
x̄ = 0.35 mm
S
T1
3
2
A1
4
5
6
7
Sp
9
E
F
G
x̄ = 1.71 mm
B
C
x̄ = 0.72 mm
8
D
I
C
A

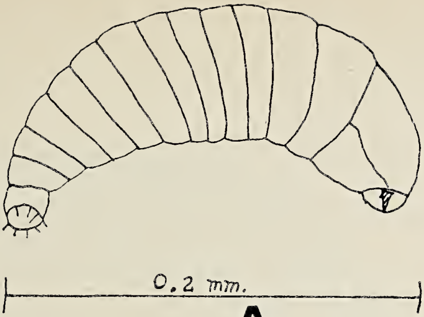
FIGURE 5

Moserina maculata, larva

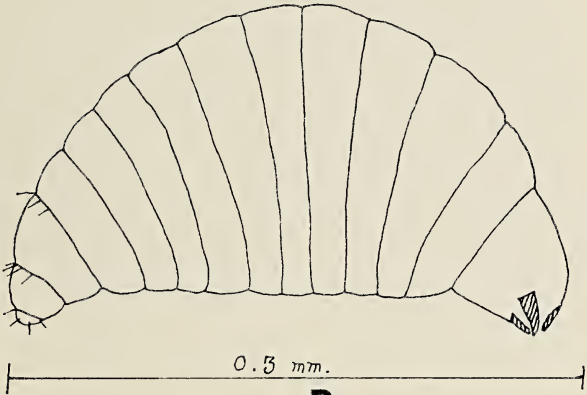
A. First instar. Lateral view. This specimen, still inside egg, was taken from inside second-instar nymph of *Pachypsylla celtidisvesicula*. The ventral portion of the head is excavated (not shown). Note disc on the 10th abdominal segment.

B. Third instar? Lateral view. Specimen taken from inside nymph of *Pachypsylla*. Note setae on caudal segments.

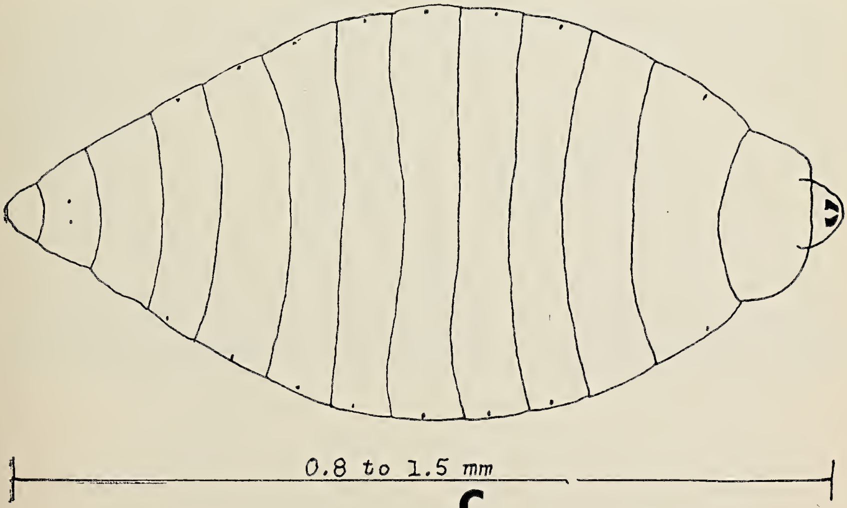
C. Last instar. Dorsal view, external.



A



B



C

FIGURE 6

Blister galls (*Pachypsylla celtidisvesicula*) infested with *Moserina maculata*

A. Lower surface of leaf showing large numbers of dead blister galls. After nymph dies, tissues of gall soon die and turn brown. Black spots indicate dead galls, lighter spots are galls that may be alive. Photograph made August 21, 1954, at Columbus, Ohio. Most parasitism of galls was by *Moserina.*

B. Last instar larva in blister gall.

C. Female pupa in young nipple gall. Before pupating, larva fed on gall and enlarged original cavity about five times.

A
B
C

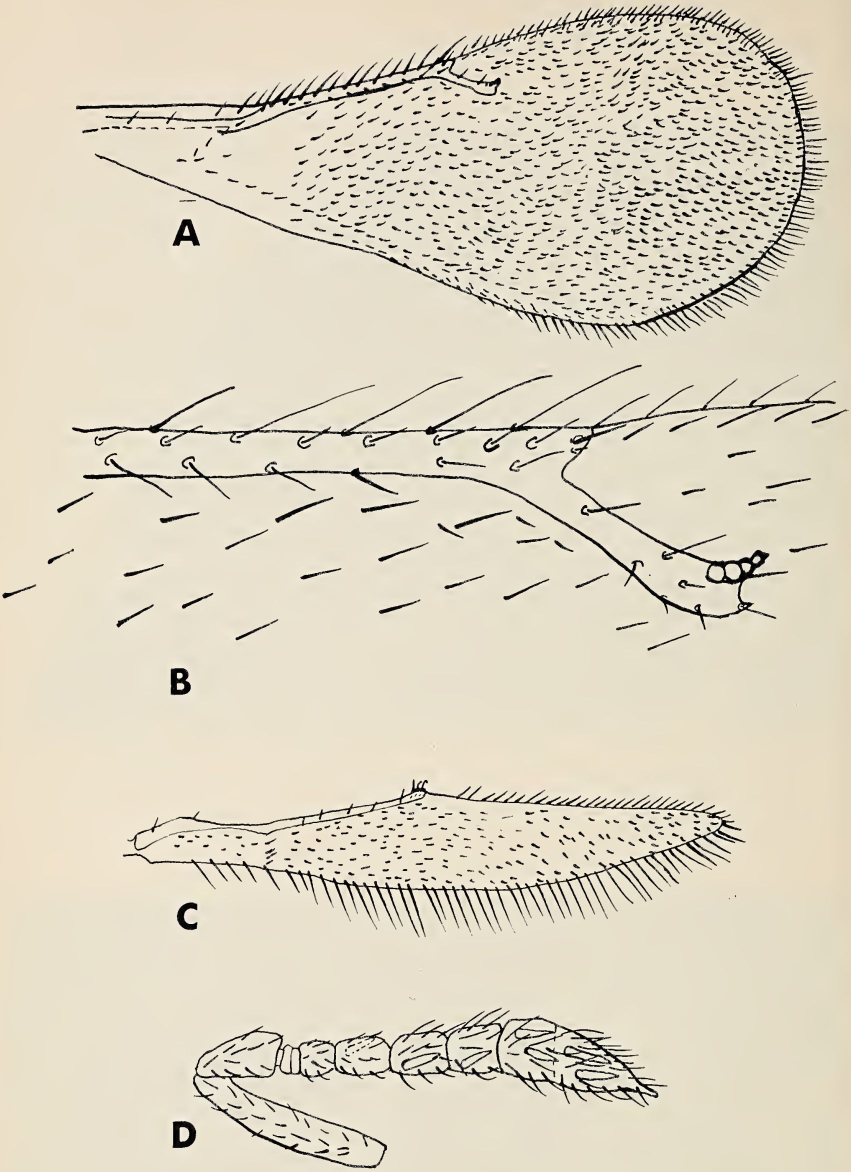


FIGURE 7

Hypertetrastichus ithacus, female

A. Front wing
B. Stigmal vein of front wing
C. Hind wing
D. Antenna

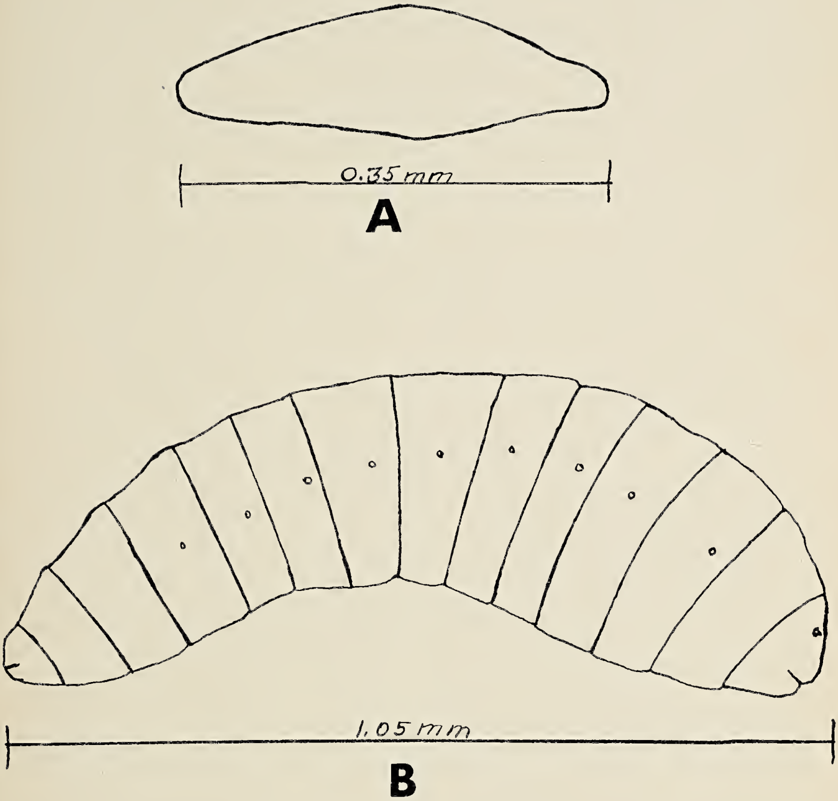


FIGURE 8

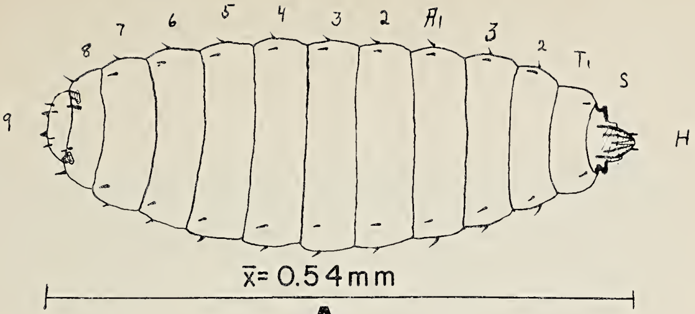
Hypertetrastichus ithacus, egg and last instar larva

A. Egg
B. Last instar larva

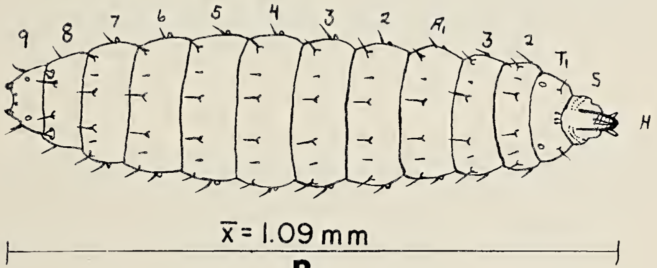
FIGURE 9

Parallelodiplosis acernea, larval stages

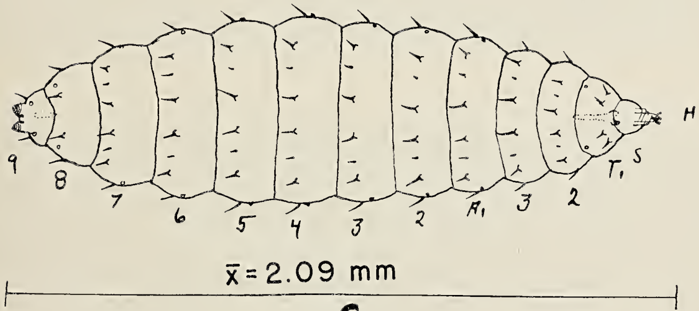
A. First instar, dorsal view
B. Second instar, dorsal view
C. Third instar, dorsal view
D. Third instar, lateral view, dorsal aspect down


A1
T1
S
H
x̄ = 0.54 mm

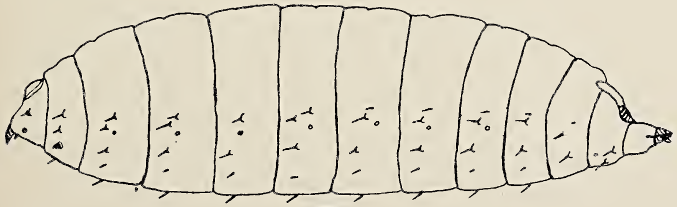
A


A1
T1
S
H
x̄ = 1.09 mm

B


H
S
T1
A1
x̄ = 2.09 mm

C



D

FIGURE 10

Various gall makers, inquilines, and parasites

A. Left, last instar larva of *Moserina maculata;* middle, last instar larva of *Hypertetrastichus ithacus;* right, dorsal aspect of pupa of *H. ithacus.*

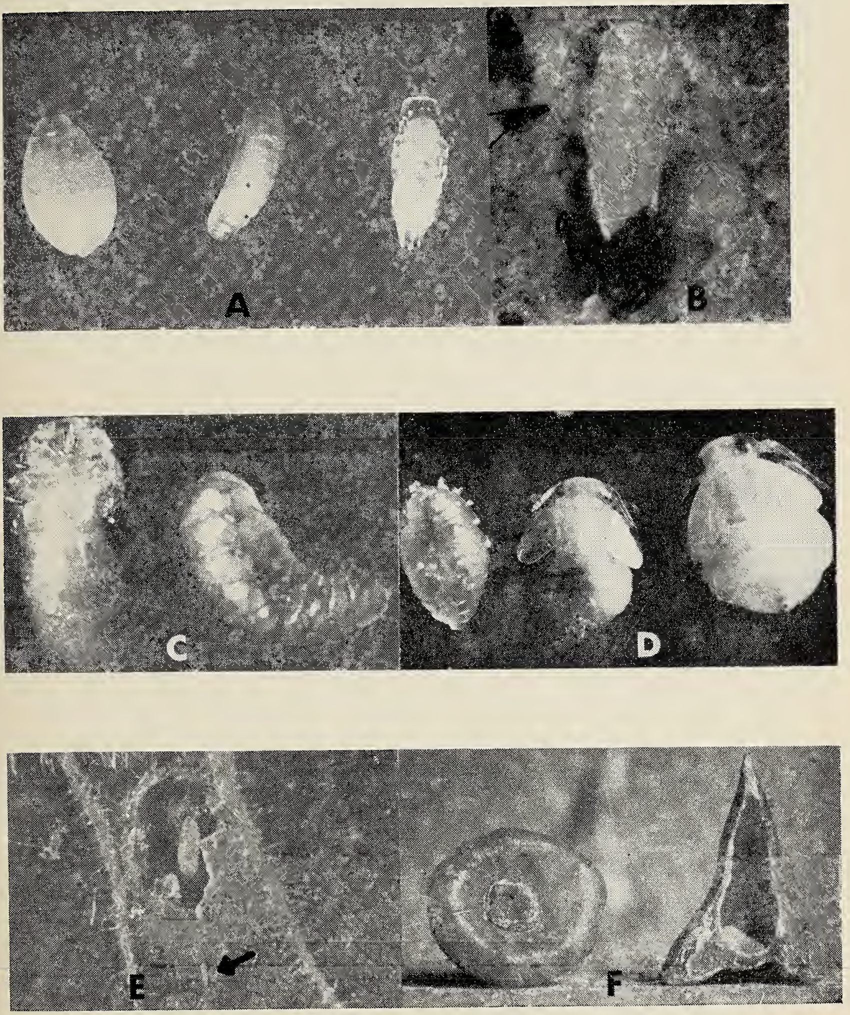
B. Early pupa of *H. ithacus* inside blister gall. Specimen fed on pupa of *Moserina,* whose empty black skin is visible.

C. Left, fourth-instar nymph of *Pachypsylla* with last instar larva of *Psyllaephagus* inside; right, last instar larva of *Psyllaephagus* extracted from similar nymph.

D. Left, last instar larva of *Achrysocharis vesiculis* with crystals of uric acid adhering to it; middle, parasitized fifth-instar nymph of *Pachypsylla celtidisvesicula* containing immature larva of *A. vesiculis.* Note blackish abdomen that is characteristic of parasitism; right, normal fifth-instar nymph of *P. celtidisvesicula* with white abdomen.

E. Last instar of *Parallelodiplosis acernea* in blister gall. Arrow points to egg at lower margin of gall. Such eggs indicate presence of *Parallelodiplosis* in gall.

F. Left, bottom of thorn gall; right, nearly mature gall containing second-instar larva of *Phytophaga* sp. Third-instar larva will occupy nearly all of the space inside gall. Columbus, Ohio, population.


A
B
C
D
E
F

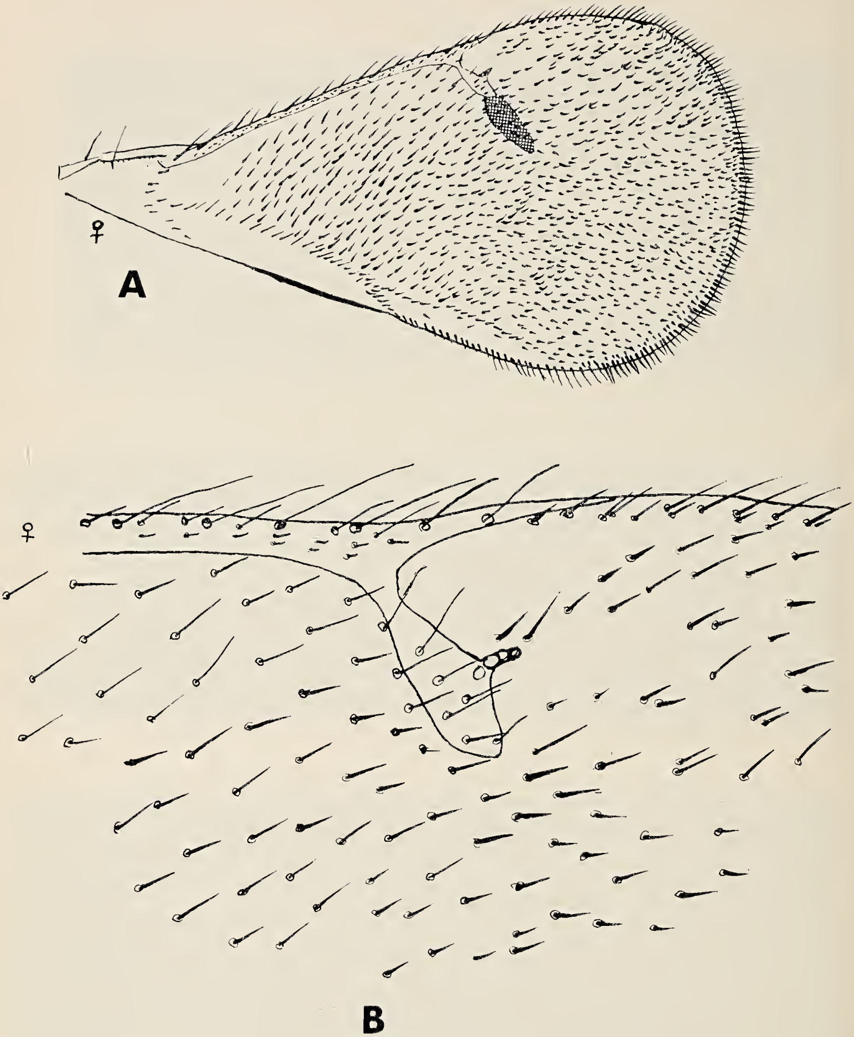


FIGURE 11

Achrysocharis vesiculis, female

A. Front wing
B. Stigma of front wing

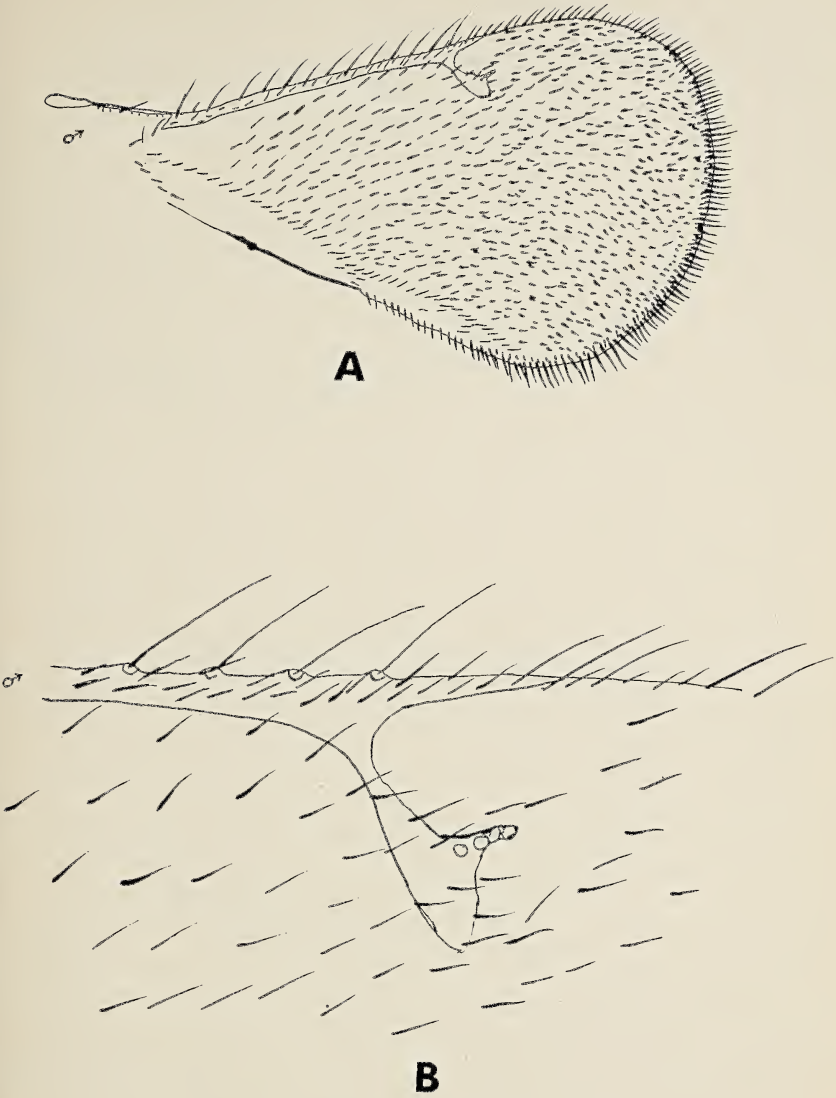


FIGURE 12

Achrysocharis vesiculis, male

A. Front wing
B. Stigma of front wing

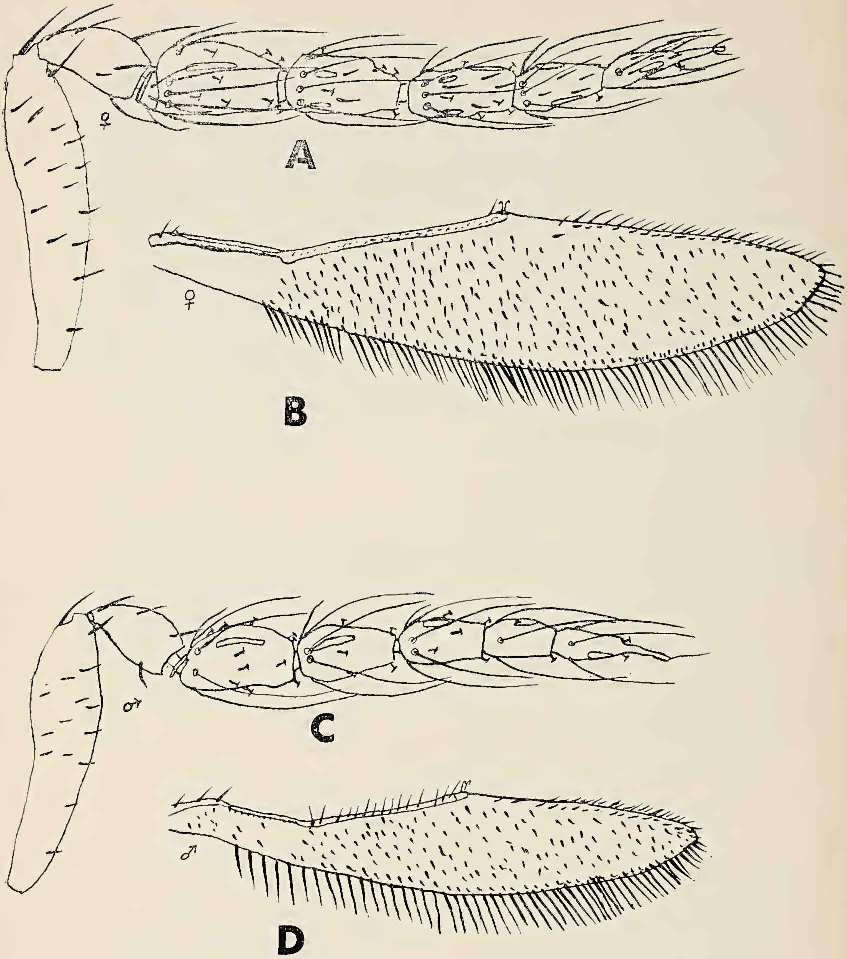


FIGURE 13

Achrysocharis vesiculis, male and female

A. Female, antenna
B. Female, hind wing
C. Male, antenna
D. Male, hind wing

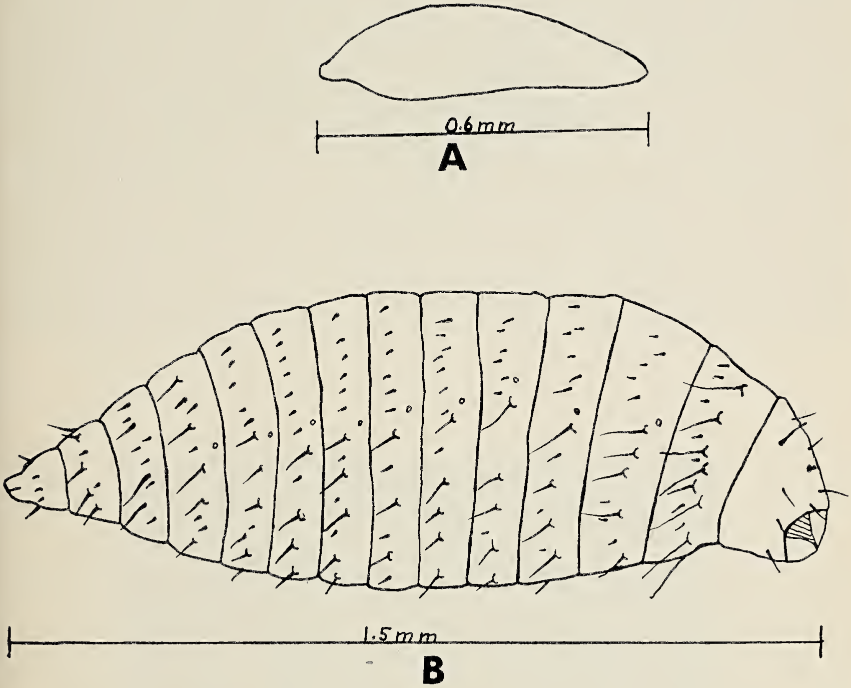


FIGURE 14

Torymus vesiculus, egg and last instar larva

A. Egg
B. Last instar larva

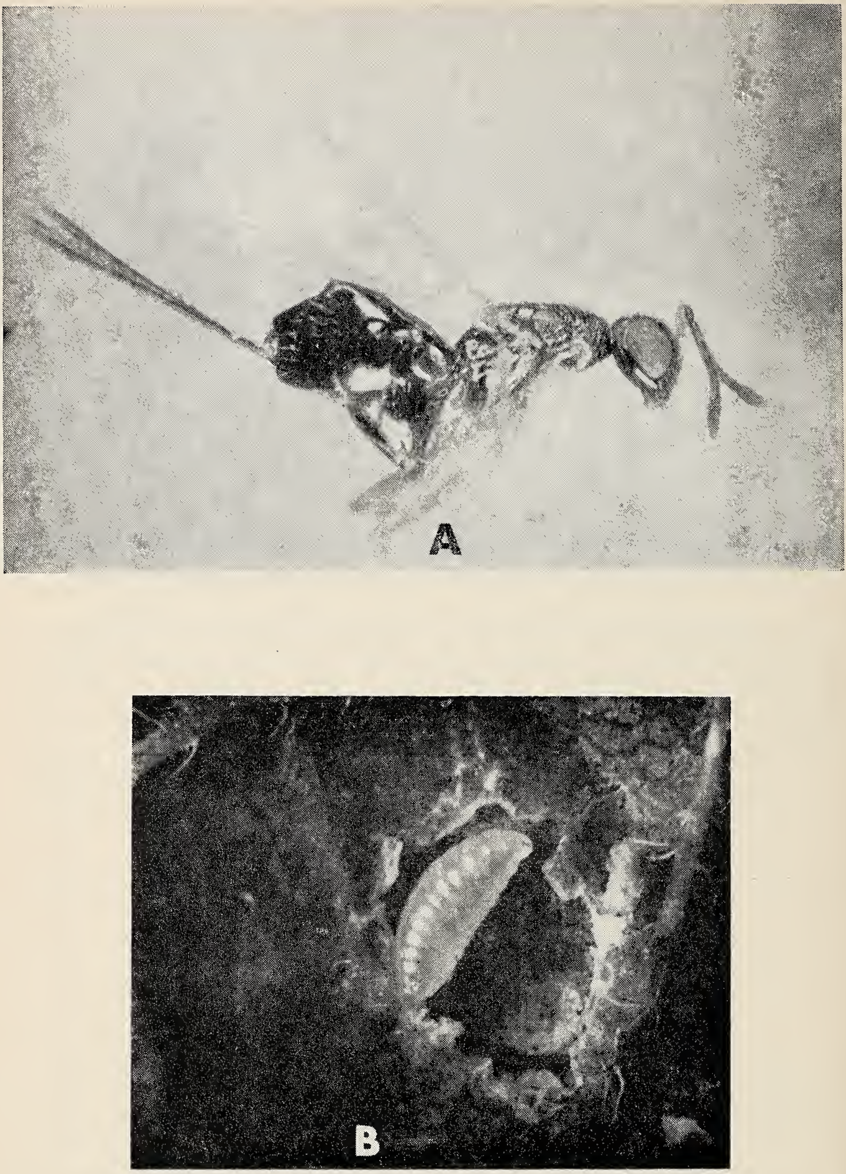


FIGURE 15

Torymus vesiculus, female and last instar larva

A. Adult female, holotype specimen. Columbus, Ohio, population. Photo by Leland Brown.

B. Mature, last instar larva inside blister gall. Host has been entirely consumed.

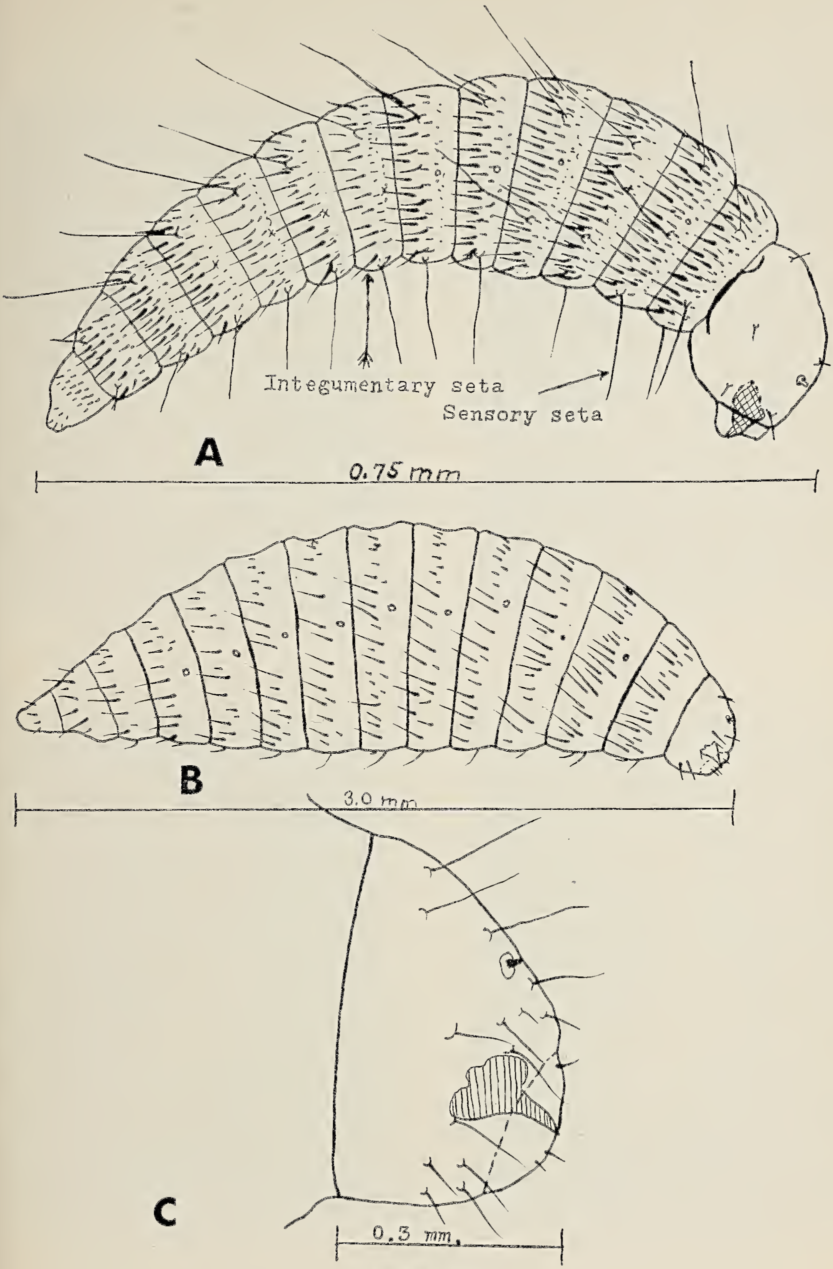


FIGURE 16

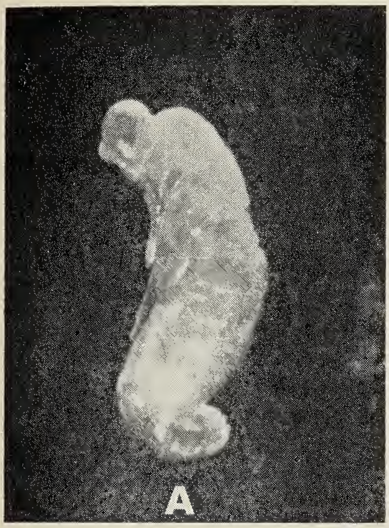
Torymus pachypsyllae, larval stages

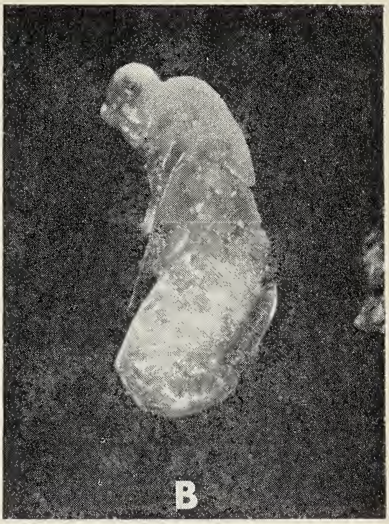
A. First-instar larva
B. Last instar larva
C. Head of last instar larva

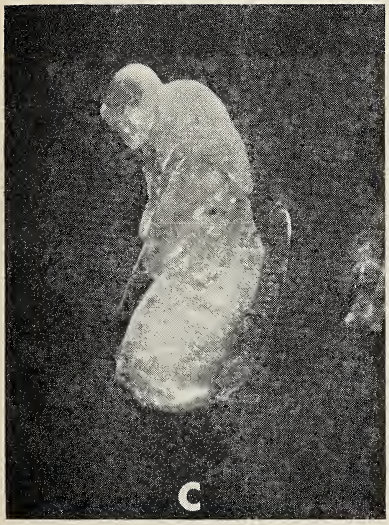
FIGURE 17

Torymus pachypsyllae, developmental stages of young female pupa

A. Newly emerged pupa a few minutes after pupation
B. Same specimen 15 minutes later
C. Same specimen 24 minutes later
D. Same specimen 18 hours later


A


B


C

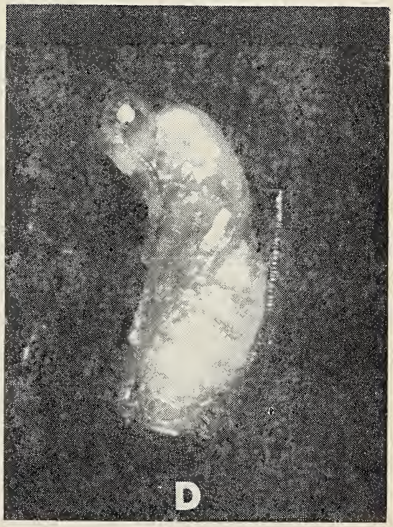
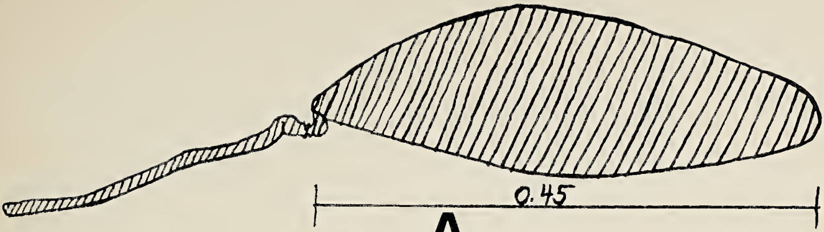

D

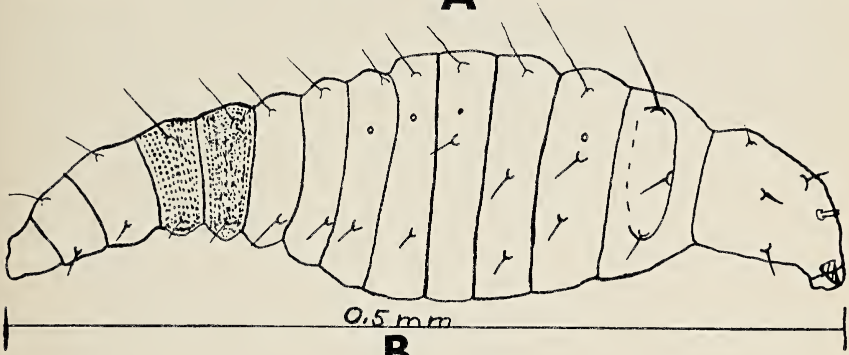
FIGURE 18

Eurytoma semivenae, egg and larval satges

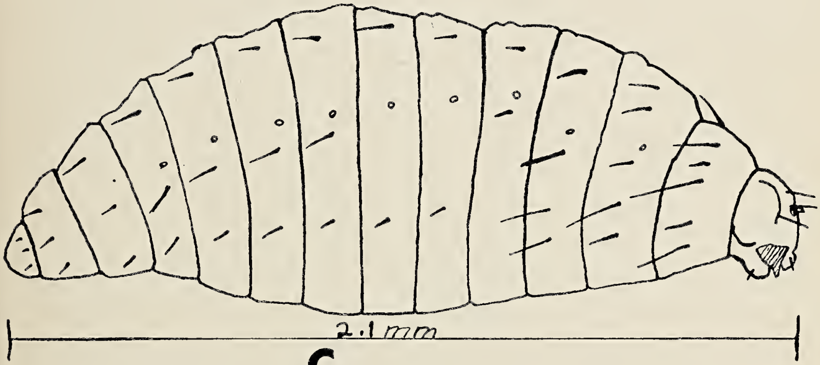
A. Egg
B. First-instar larva, slightly flattened at middle. Microspines shown only on abdominal segments 6 and 7.
C. Last instar larva, slightly flattened at middle
D. Detail of head of last instar larva



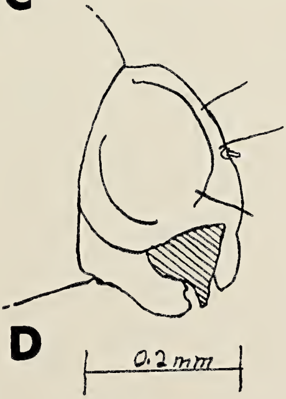
A



B



C



D

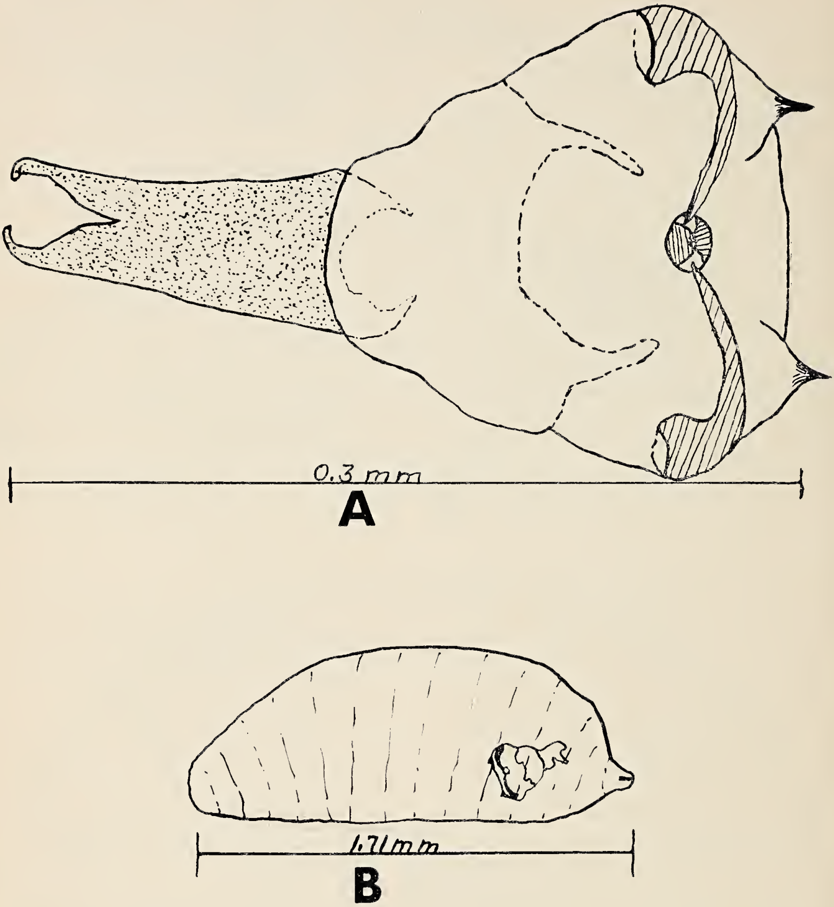


FIGURE 19

Trichacis sp., first-instar larva

A. First-instar extracted from host. Note unorthodox shape of antennae and mandibles. Membraneous part of "tail" represented by stippling.

B. First-instar larva "in situ" inside third-instar larva of *Phytophaga* sp. after clearing with lactic acid

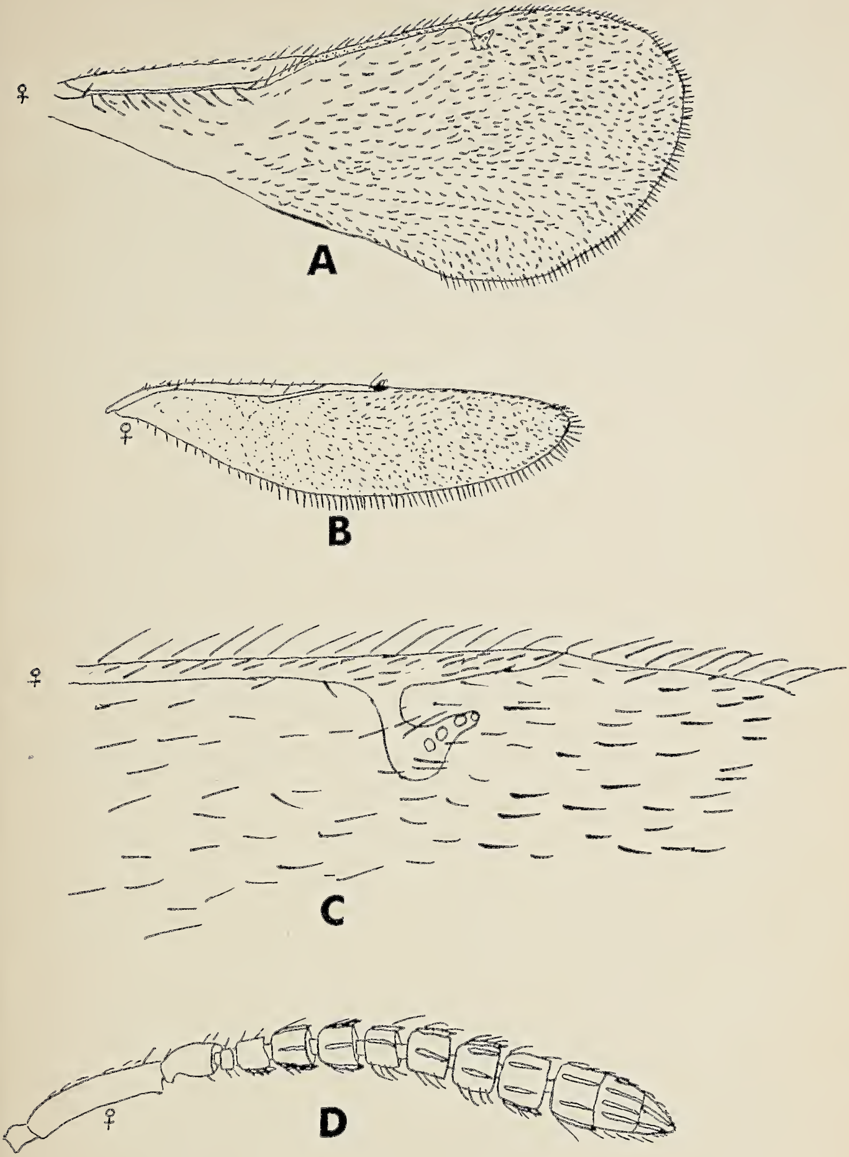


FIGURE 20

Torymus diabolus, female

A. Front wing
B. Hind wing
C. Stigma of front wing
D. Antenna

FIGURE 21

Torymus diabolus, larval stages

A. First-instar larva, dorsal view
B. First-instar larva, side view (microspines not shown)
C. First-instar larva, ventral view of head
D. Last instar larva. Note difference in anatomy between *T. diabolus* and the two species of *Torymus* that attack psyllids.

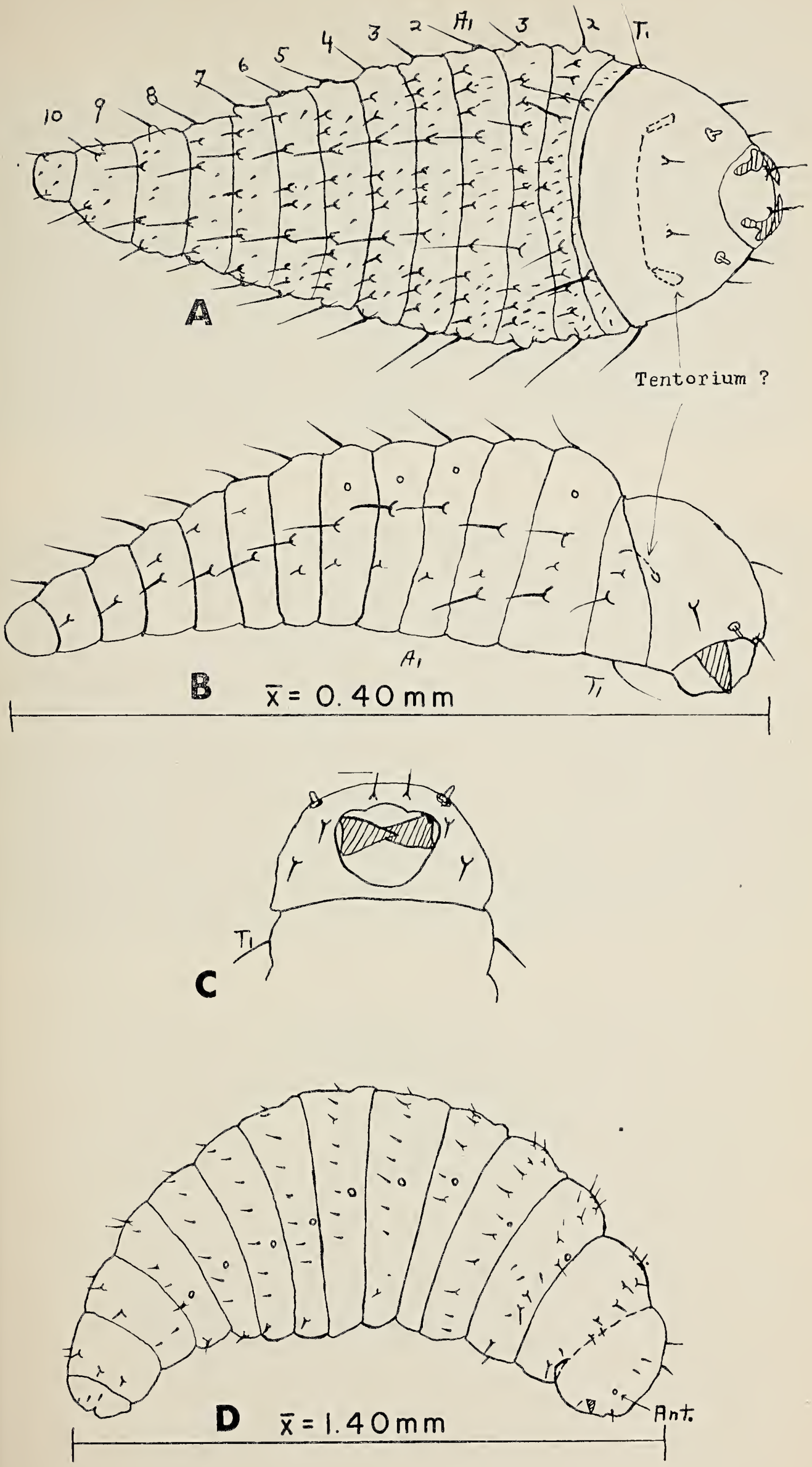

10
9
8
7
6
5
4
3
2
A1
3
2
T1
Tentorium ?
A
A1
T1
B
x̄ = 0.40 mm
T1
C
Ant.
D
x̄ = 1.40 mm

FIGURE 22

Parasites of gall makers

A. Egg of *Torymus pachypsyllae.* Egg of *T. vesiculus* is almost identical in shape, but smaller. Egg is not attached to gall.

B. Egg of *Torymus diabolus.* Egg is suspended inside gall.

C. Egg of *Eurytoma semivenae* on abdomen of fifth-instar nymph of *Pachypsylla celtidismamma.* Arrow points to black area left of egg where nymph was stung.

D. Last instar of *E. semivenae.* Note whitish-brown crystals of uric acid on and around larva.

E. Fourth-instar larva of *Torymus pachypsyllae* beside partially sucked nymph of *P. celtidismamma.* Head of larva is facing camera.

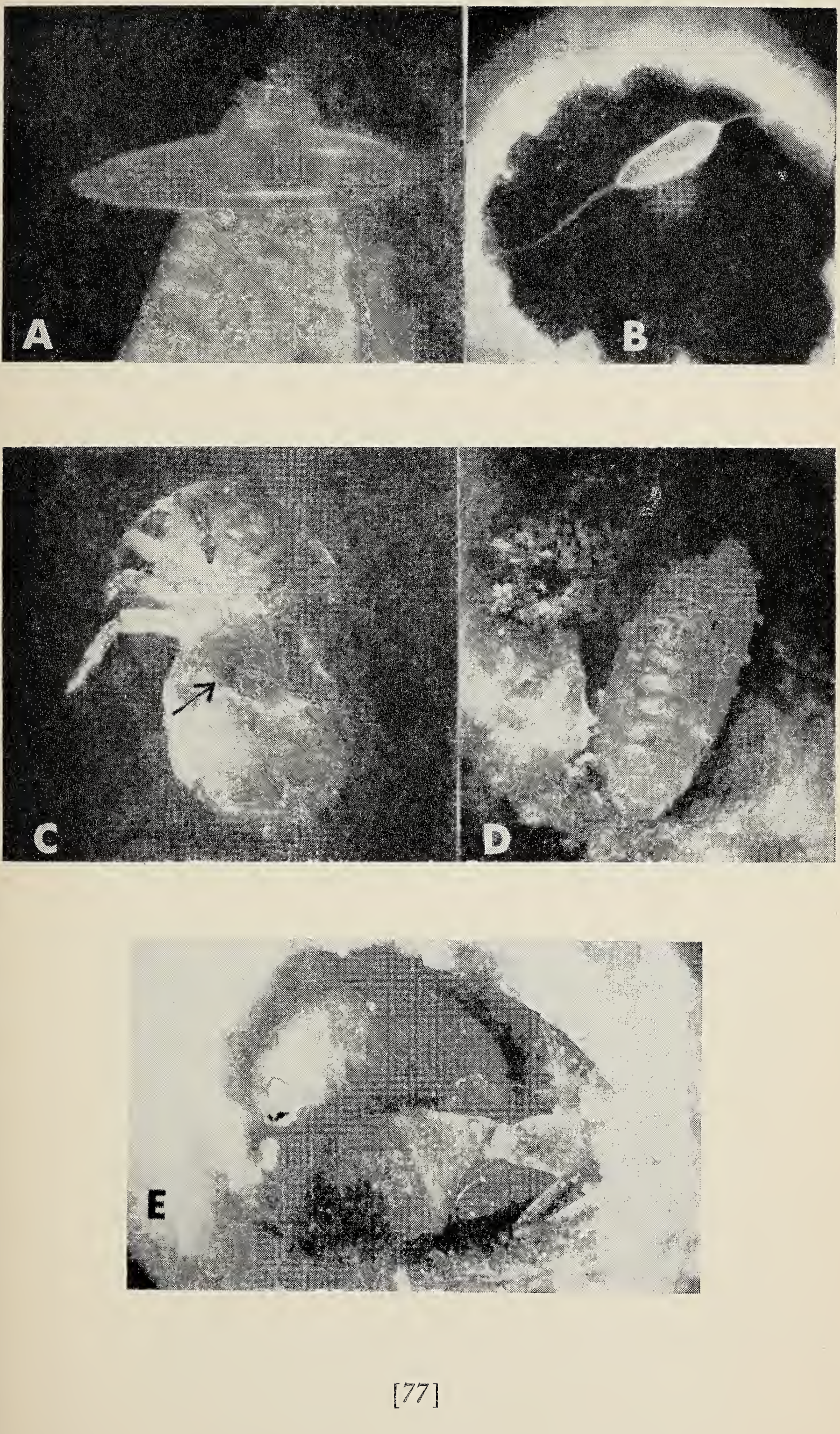

A
B
C
D
E

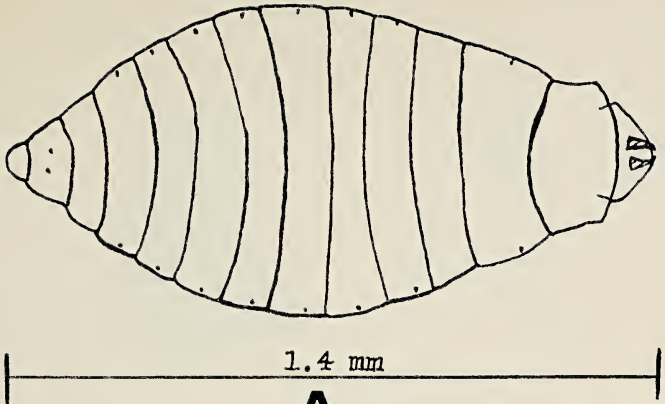
FIGURE 23

Achrysocharis spiniformis and *Psyllaephagus pachypsyllae,* larvae

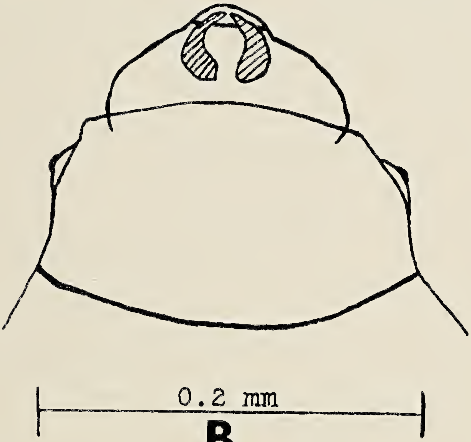
A. Last instar larva of *A. spiniformis.* The larva of *A. vesiculis* is nearly identical.

B. Detail of head and first thoracic segment of *A. spiniformis*

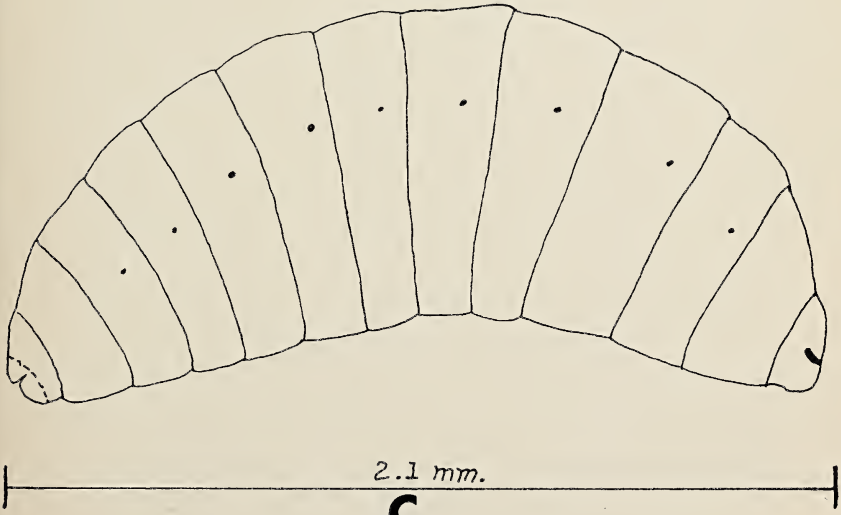
C. Last instar larva of *Psyllaephagus pachypsyllae.* Larva is nondescript, reduced, glabrous, and milk white in color. The spiracles, mandibles, and antennae are reduced.



A



B



C

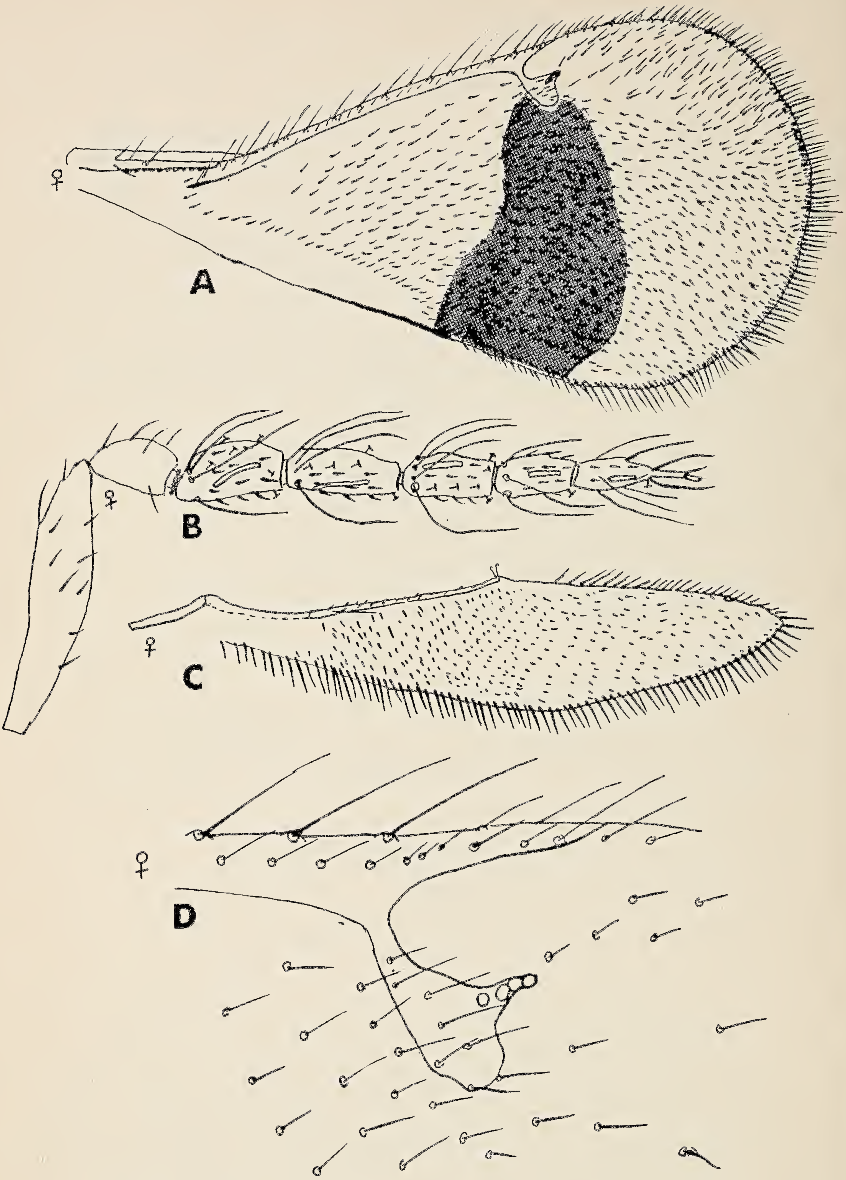


FIGURE 24

Achrysocharis spiniformis, female

A. Front wing
B. Antenna
C. Hind wing
D. Stigma of front wing

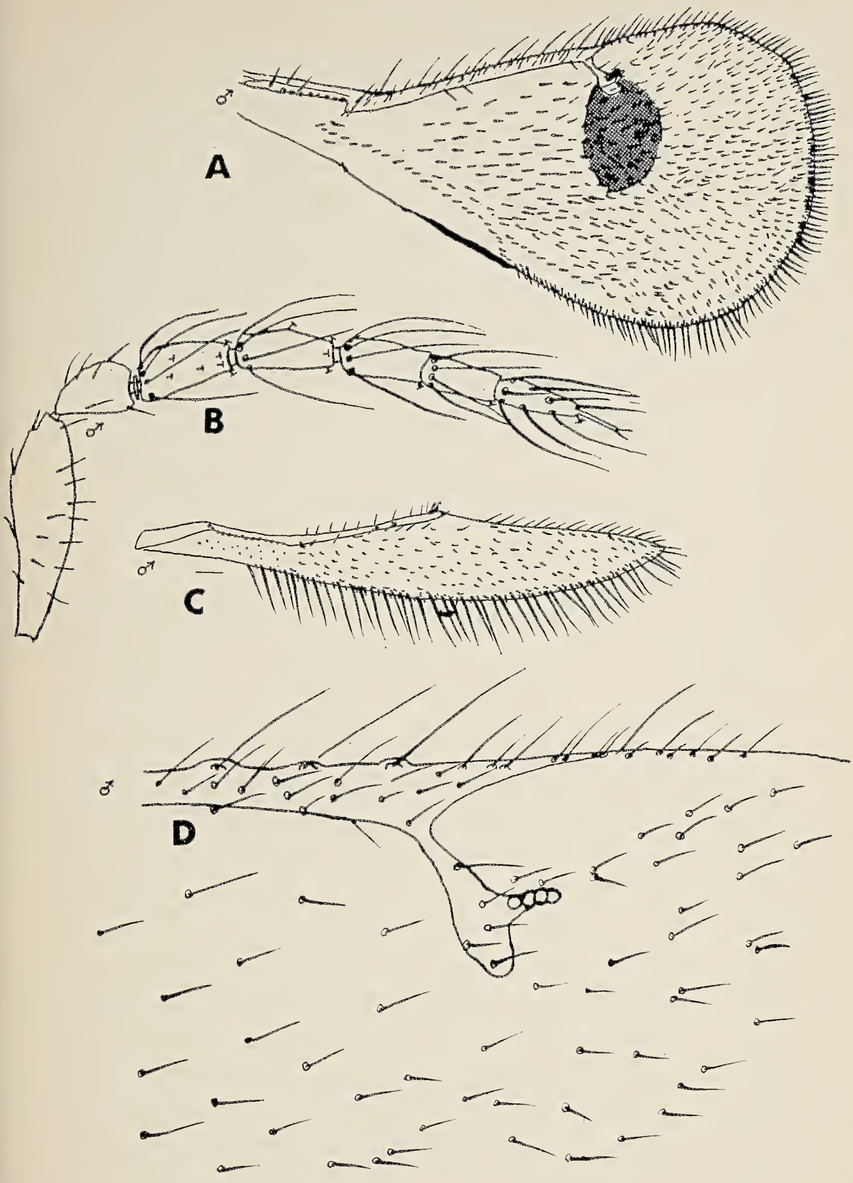


FIGURE 25

Achrysocharis spiniformis, male

A. Front wing
B. Antenna
C. Hind wing
D. Stigma of front wing

FIGURE 26

Pachypsylla celtidisvesicula and parasites, life history charts

Explanation of terms

E. Egg

1, 2, 3, 4, 5. First-, second-, third-, fourth-, and fifth-instar nymphs

S. Psyllid nymph stung by *Achrysocharis vesiculis.* Presumably egg is inside nymph.

I. Immature larva

P. Pupa

A. Adult

Solid circles represent observations in field; solid lines through circles are periods of greatest abundance of each stage. Arrows in last column show stage that overwinters. Dotted lines indicate probable occurrence of stage when no observations were made.

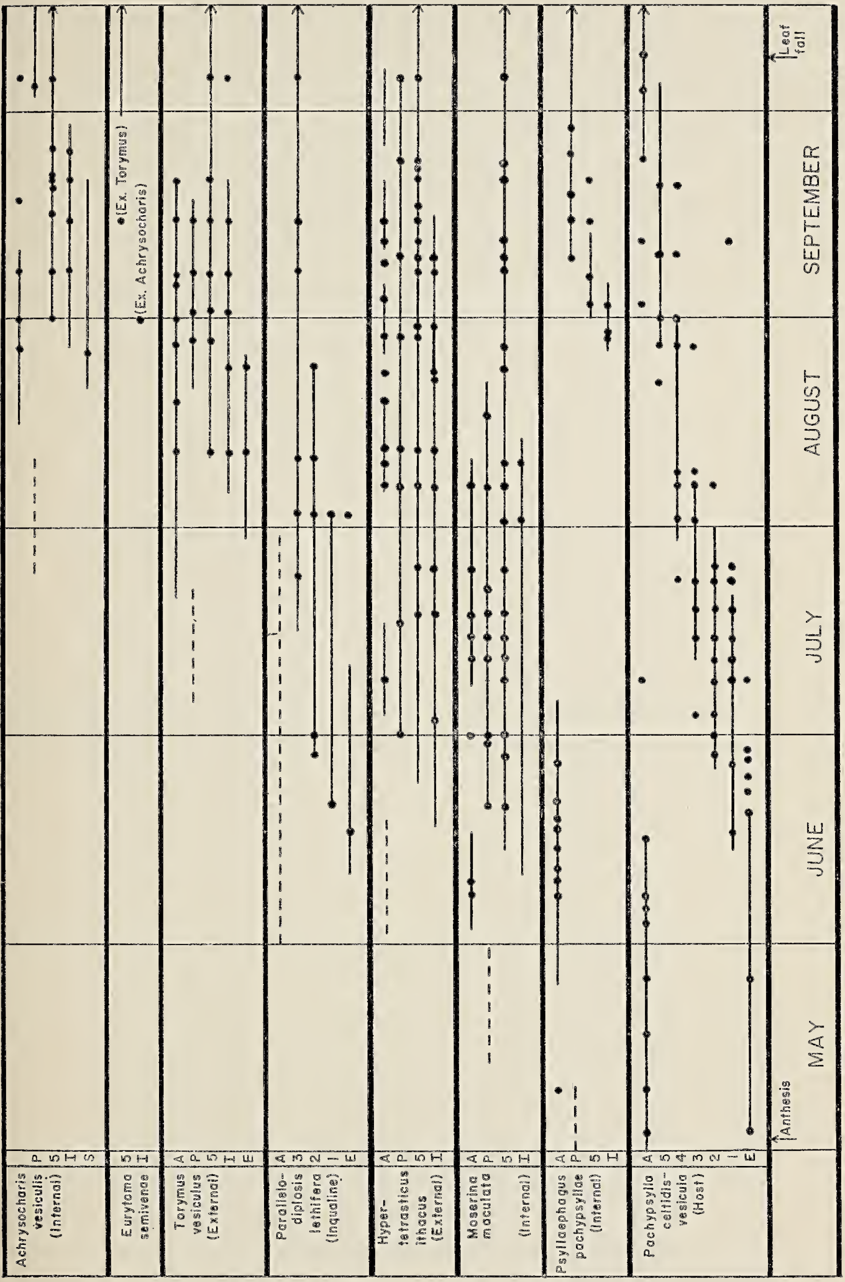

Achrysocharis vesiculis (Internal)
P
5
I
S
Eurytoma semivenae
5
I
(Ex. Torymus)
(Ex. Achrysocharis)
Torymus vesiculus (External)
A
P
5
I
E
Parallelo-diplosis lathifera (Inquiline)
A
3
2
1
E
Hyper-tetrasticus ithacus (External)
A
P
5
I
Moserina maculata
(Internal)
A
P
5
I
Psyllaephagus pachypsyllae (Internal)
A
P
5
I
Pachypsylla celtidis-vesicula (Host)
A
5
4
3
2
1
E
Anthesis
MAY
JUNE
JULY
AUGUST
SEPTEMBER
Leaf fall

FIGURE 27

Pachypsylla celtidismamma and parasites, life history charts

Explanation of terms

E. Egg
1, 2, 3, 4, 5. First-, second-, third-, fourth-, and fifth-instar nymphs.
I. Imature larva
D. Excavated galls eaten by larvae of *Conotrachelus buchanani*
P. Pupa
A. Adult

Solid circles represent observations in field; solid lines through circle are periods of greatest abundance of each stage. Arrows in last column show stage that overwinters. Dotted lines indicate probable occurrence of stage when no observations were made.

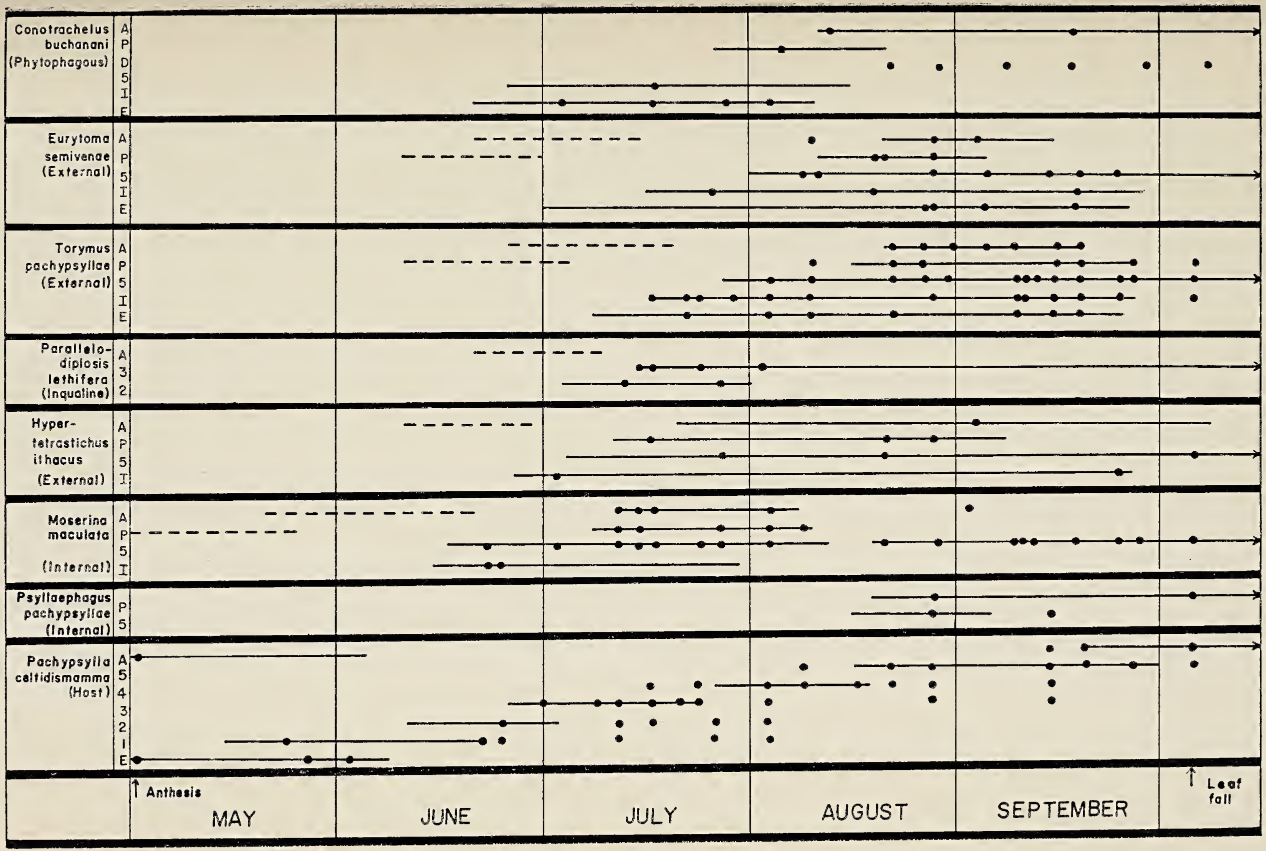

Conotrachelus buchanani (Phytophagous)
A
P
D
5
I
E
Eurytoma semivenae (External)
A
P
5
I
E
Torymus pachypsyllae (External)
A
P
5
I
E
Parallelo-diplosis lethifera (Inquiline)
A
3
2
Hyper-tetrastichus ithacus (External)
A
P
5
I
Moserina maculata (Internal)
A
P
5
I
Psyllaephagus pachypsyllae (Internal)
P
5
Pachypsylla celtidismamma (Host)
A
5
4
3
2
1
E
Anthesis
MAY
JUNE
JULY
AUGUST
SEPTEMBER
Leaf fall

FIGURE 28

Height of nipple gall and instar of nymph of *Pachypsylla celtidismamma*

Explanation of terms

E. Egg
1, 2, 3, 4, 5. First-, second-, third-, fourth-, and fifth-instar nymphs of *P. celtidismamma.*
A. Adult

Large circles connected by solid line are mean heights for 30 nipple galls each at selected dates. Small circles show height extremes of samples.

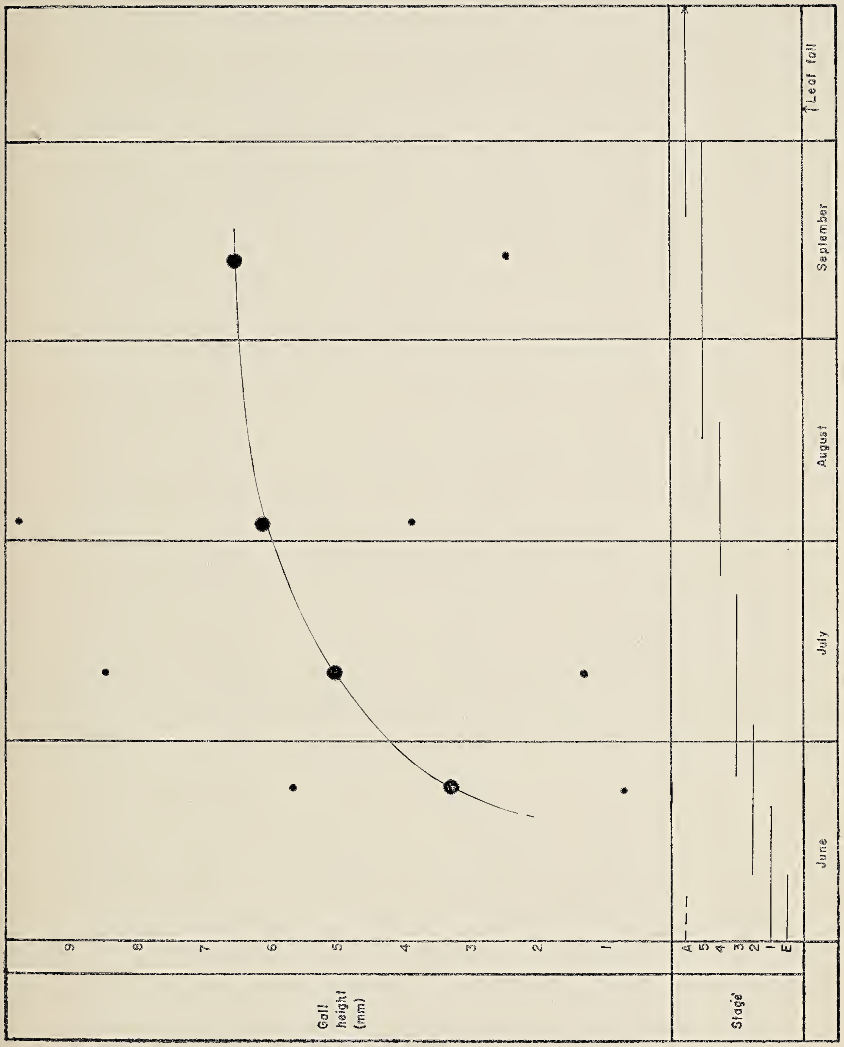

Gall height (mm)
9
8
7
6
5
4
3
2
1
Stage
A
5
4
3
2
1
E
June
July
August
September
Leaf fall

FIGURE 29

Phytophaga sp. and parasites, life history charts

Explanation of terms

E. Egg
1, 2, 3. First-, second-, and third-instar larvae.
3c. Third-instar larva in cocoon
P. Pupa
A. Adult
(A). Adult in diapause, still inside host skin in gall (*Trichacis*)
I. Immature larva
5. Mature larva

Solid circles represent observations in field; solid lines through circles are periods of greatest abundance of each stage. Arrows in last column show stage that overwinters. Dotted lines indicate probable occurrence of stage when no observations were made.

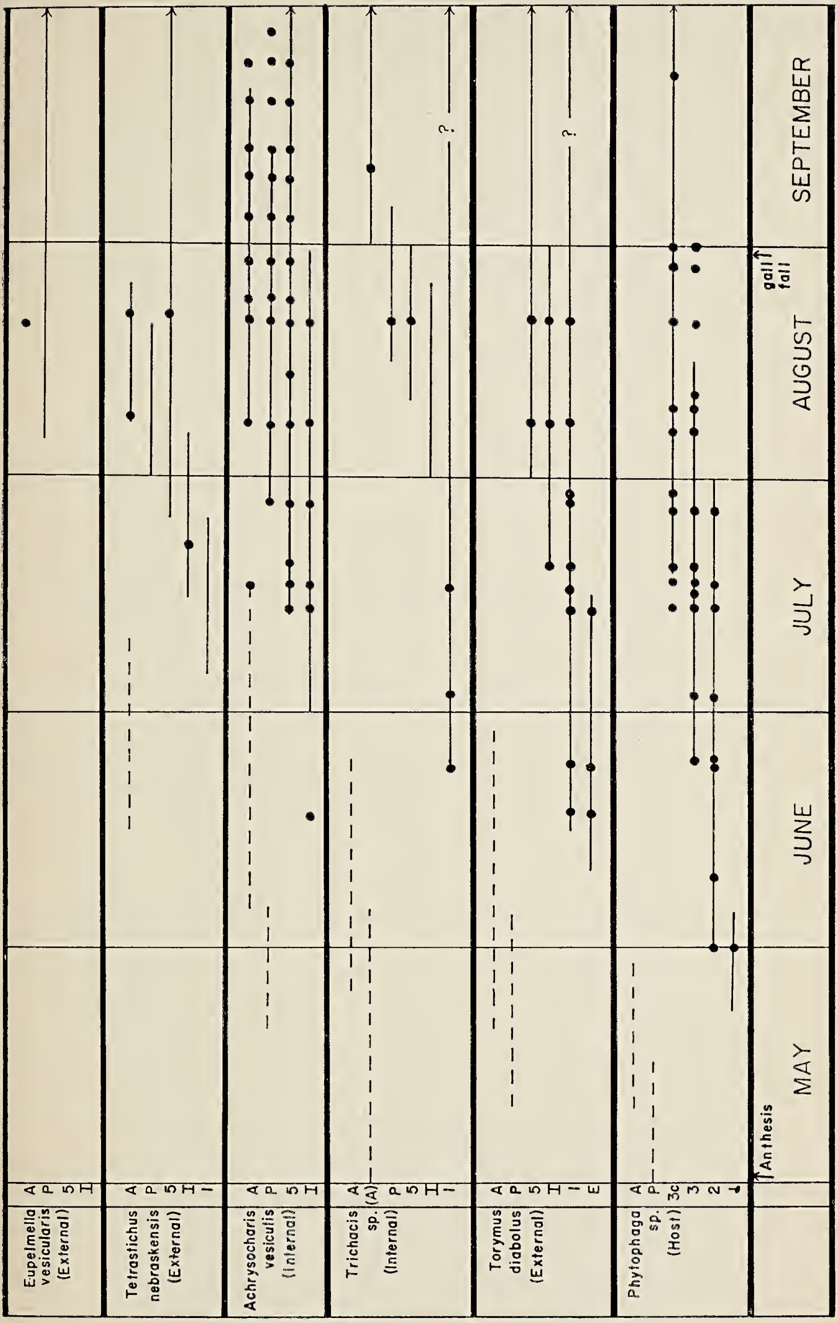

Eupelmella vesicularis (External)
A
P
5
I
Tetrastichus nebraskensis (External)
A
P
5
I
I
Achrysocharis vesiculis (Internal)
A
P
5
I
Trichacis sp. (Internal)
A
(A)
P
5
I
I
?
Torymus diabolus (External)
A
P
5
I
I
E
?
Phytophaga sp. (Host)
A
P
3c
3
2
1
Anthesis
gall fall
MAY
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 30

Height of thorn gall and instar of larvae of *Phytophaga* sp.

Explanation of terms

E. Egg
1, 2, 3. First-, second-, and third-instar larvae of *Phytophaga* sp.
C. Third-instar larva that formed cocoon.

Large circles connected by solid lines are mean heights for 30 thorn galls at selected dates. Small circles show height extremes of samples.

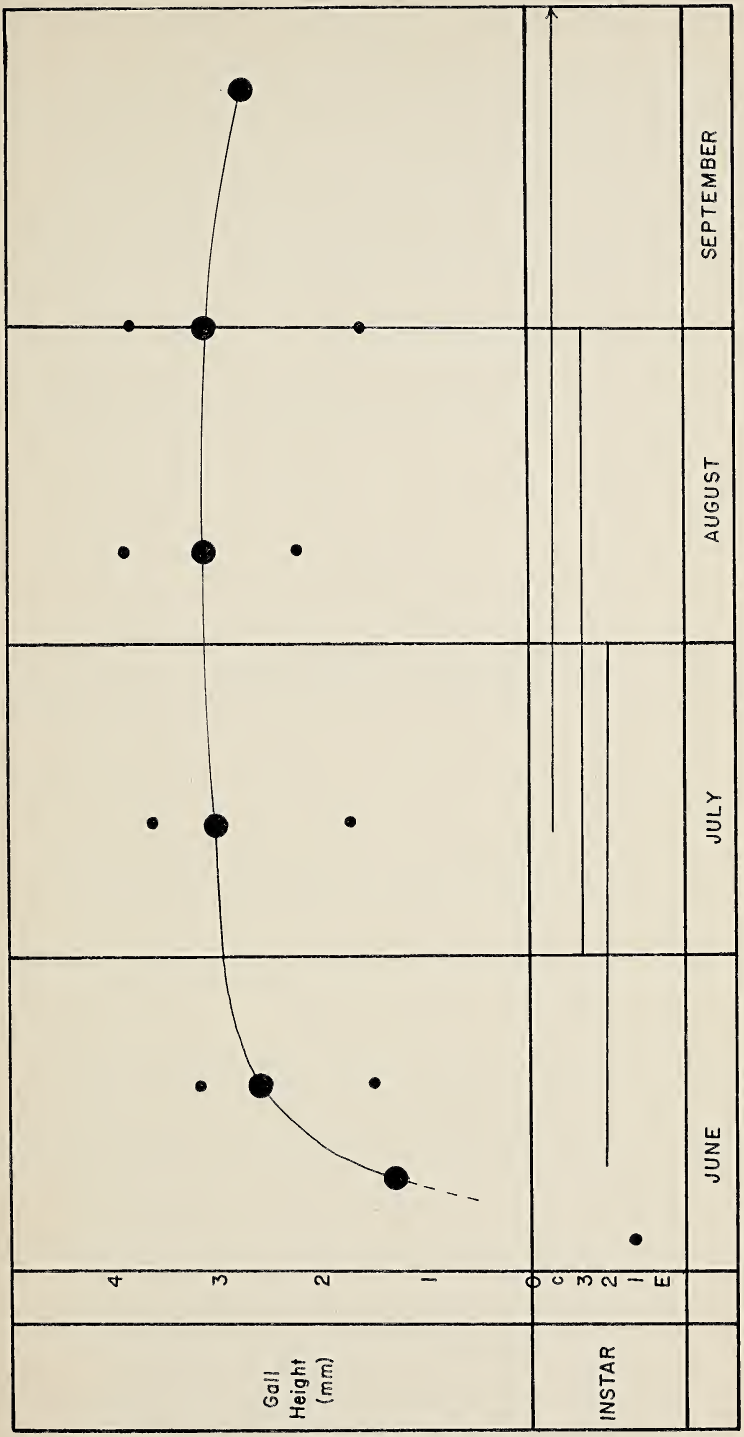
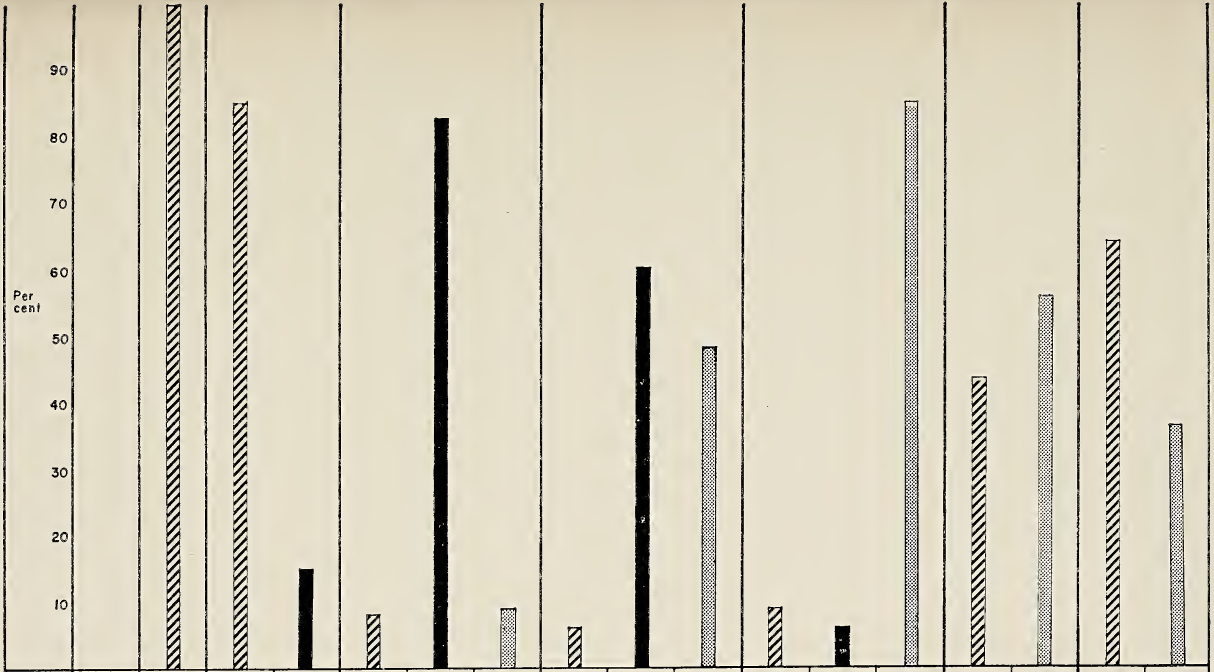

Gall Height (mm)
4
3
2
1
0
INSTAR
C
3
2
1
E
JUNE
JULY
AUGUST
SEPTEMBER

FIGURE 31

Moserina maculata, stage histogram

Relative abundance of last-instar larvae, pupae, and adults of parasite at various dates when psyllid nymphs occupied galls. The egg and early instars are not shown because they occurred inside nymphs and could not be located in numbers.



Stage	None	5	5	Pupa	5	Pupa	Em.	5	Pupa	Em.	5	Pupa	Em.	5	Em.	5	Em.
Galls (n)	100	100	17	3	6	63	7	7	69	48	4	3	40	42	55	87	48
Per cent	0	100	85.0	15.0	7.7	82.9	9.1	6.2	60.2	42.5	8.5	6.4	85.1	43.3	56.7	64.4	35.6
Source	Lower Coy Glen	Lower Cay Glen	Lower Coy Glen		Culver Rd.			Culver Rd.			Culver Rd.			Culver Rd.		Culver Rd.	
Date	16 VI 57	20 VI 57	27 VI 57		14 VII 56			24 VIII 56			16 VIII 56			29 VIII 56		5 X 56	

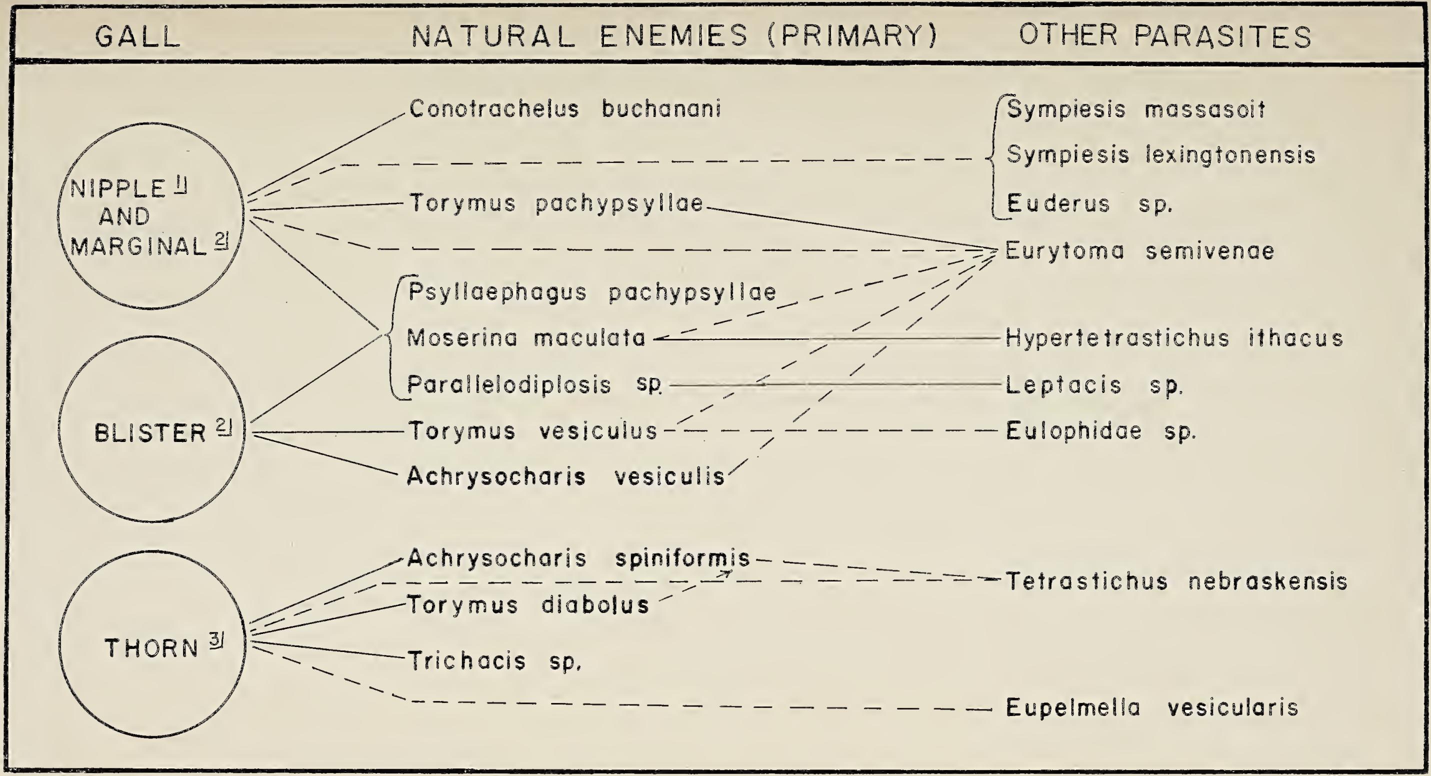
FIGURE 32

Interrelationships of natural enemies of hackberry galls in the vicinity of Ithaca, N.Y.

This figure shows the complex of parasites that theoretically can be found on a single leaf of the hackberry. The galls are illustrated in the left column by the circles, and the natural enemies are in columns to the right of the circles. Lines connecting the natural enemies and galls read from right to left. Solid lines connect the natural enemies with the host they usually attack, whereas broken lines lead to hosts occasionally attacked.

The middle column is termed "natural enemies (primary)" instead of "primary parasites" because of the weevil *Conotrachelus bucanani* and of the midge *Parallelodiposis acernea,* which are not true parasites. They feed on gall tissue and only accidentally kill the gall makers. All other species listed under the column are hymenopterous parasites.

The heading "other parasites" contains miscellaneous ecological groups of hymenopterous parasites. *Sympiesis massasoit, S. lexingtonensis,* and *Euderus* sp. are normally found in mines of *Lithocolletis* spp. that are common on leaves of hackberry. *Hypertetrastichus ithacus* and *Leptacis* sp. are true secondary parasites, whereas *Eurytoma semivenae* is usually secondary but occasionally attacks the gall maker. *Eulophidae* sp., *Tetrastichus nebraskensis,* and *Eupelmella vesicularis* are general parasites that are occasionally found in hackberry galls



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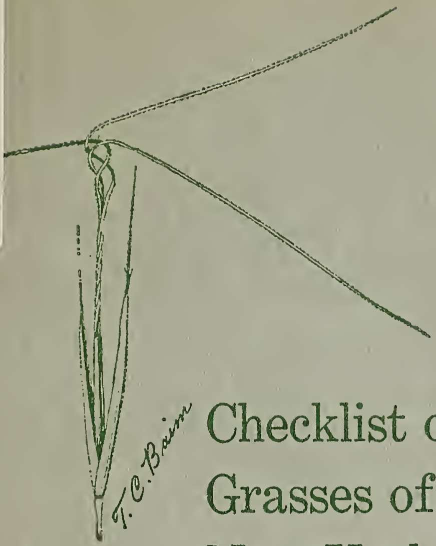
[1] *Pachypsylla celtidismamma.* [2] *Pachypsylla celtidisvesicula.* [3] *Phytophaga* sp. near *spiniformis.*

Q
11
N82X
NH



Checklist of the Grasses of New York State

Stanley Jay Smith
Associate Curator of Botany
New York State Museum and Science Service

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The University of the State of New York
The State Education Department

ALBANY, NEW YORK

OCTOBER 1965

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The University of the State of New York
ALBANY, NEW YORK
The State Education Department
1784
OCTOBER 1965

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The University of the State of New York

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Contents

PAGE

1 **INTRODUCTION**

6 **CHECKLIST OF RECORDED GRAMINEAE**

26 *Rejiciendae*

26 *Hybrids*

27 *Minor Variants*

32 **CHECKLIST OF DESIDERATA**

37 **PAGES FOR ADDITIONS**

39 **SYNONYMY**

42 **REFERENCES FOR DESCRIPTIONS**

43 **BIBLIOGRAPHY**

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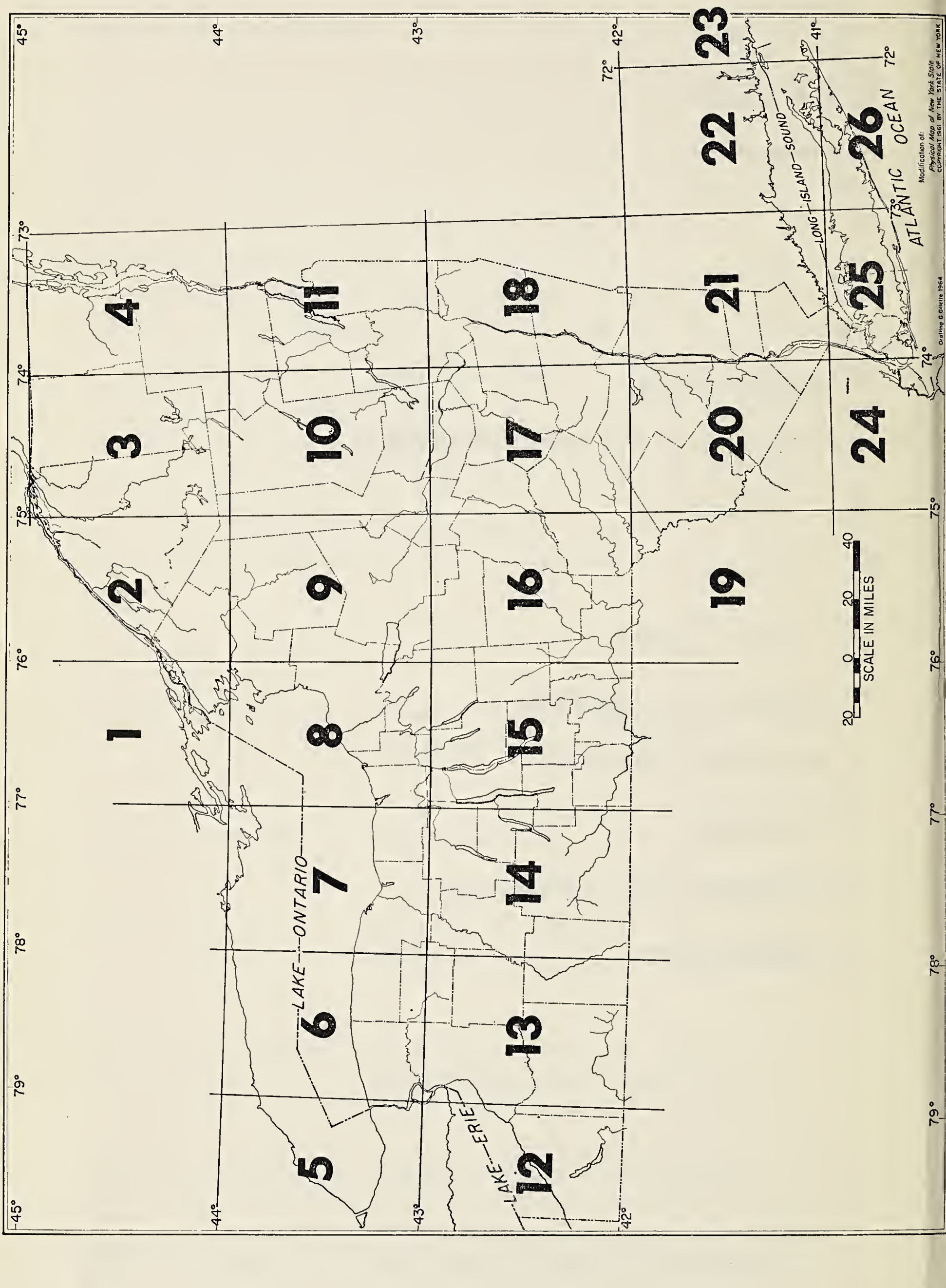

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Introduction

THIS CHECKLIST SUMMARIZES the author's knowledge of the distribution of grasses within New York State. It is here presented to encourage further exploration by all interested botanists, with the hope that a detailed grass flora can eventually be produced.

The author's interest in the grasses started in 1935, at the New York State College of Agriculture, when Prof. Karl M. Wiegand suggested the family as a problem for undergraduate research. When, on the author's appointment to the State Museum in 1947, the former State Botanist, Dr. Homer D. House, suggested revising the *Annotated List of the Ferns and Flowering Plants of New York State* (NYS Mus. Bul. 254), this group seemed a logical place to start.

In the years since 1935, the author has made collections or observations in every one of the State's 62 counties. An attempt has been made to check all other available specimens. By comparison, in 1947, the files of the Museum showed a number of counties with few recorded grasses (one with only four) ; no county now has less than 50. Supporting specimens for 12 taxa, previously reported for the State, could not be located. These are listed in the appendix. On the other hand, 100 have been added to those reported in 1924 by Dr. House. Of these, 53 have not been cited for New York State in the current editions of *Hitchcock's Manual,* or the major regional floras.

Attention has been paid both to natives and to introductions. Of the natives, 22 have not been collected in the last 25 years. These may now be extinct in this State, but diligent search should yet relocate some of them at the original or new stations. Conversely, five new natives have been collected in that period. As for the introductions, 62 have not been found since 1940. Over two-thirds of the 62 have but one recorded locality, and three-fifths of the two-thirds were found on woolwaste at Yonkers. A number of others were collected only on Cobb Hill, Rochester. Recent search for these species at the two stations has proved unfruitful. In contrast, 22 new weeds or escapes have been collected since 1940. Similarly, the majority of these 22 are known from but one station.

The composition of the grass-flora is shifting. Some introductions from the Old World which were relatively rare at the time House compiled his *Annotated List* are now widespread. Two good examples are *Bromus inermis inermis,* currently found in nearly every part of the State, and *Corynephorus canescens,* now locally abundant in much of Long Island. *Setaria faberii,* which first appeared in the State in 1925 and which was collected therein only three times before 1940, is now widespread in disturbed soils south of the Adirondacks, and is known from 82 stations. Native American species (particularly those of open soils), local or unknown from the State in 1924, are increasing upstate. Examples are *Aristida basiramea* and *Eragrostis spectabilis.* Except for the Coastal Plain area, including New York City and adjoining Westchester County, the native flora seems to be holding its own. Of the nine native taxa missing from upstate New York, only one was known from more than four stations. A detailed analysis of these changes is left to the proposed comprehensive floristic account.

This current listing of the grass family of New York State comprises 88 genera, 333 species. Two or more varieties or subspecies are listed for 28 species, so that there are 33 additional infraspecific names, making a total of 366 line-entries.

For purposes of spacing exploration, the State is divided into 26 districts, each a degree-quadrangle or part of one, bounded by meridians and parallels, one degree apart, and numbered as in the frontispiece map. The following symbols indicate the presence of taxa in the districts:

X	x	specimen examined by the author
L	l	authentic literature reports, without available specimens
H	h	specimen identified by Dr. Homer D. House, not seen by the author
O	o	observation by the author, without supporting specimens
V	v	district approximate
?		specimen seen, but locality questioned

Lower-case symbols indicate that the item is not established. Reference should be made to the standard manuals as to whether a species or race is native or an introduction.

A total of 3577 definite district-records is reported here, and is distributed as follows:

Districts	Number of recorded taxa
1 3 5 12 19 23	51–100
2 4 6 10 14 16 17 20	101–150
7 8 9 11 13 15 18 21 22 24 26	151–200
25	251–300

Of the 366 recorded species and major races, 8 introduced and 10 native are recorded for all 26 districts. A number more are recorded for so many districts (and with the "absences" so scattered) that it is obvious they will shortly be listed for all 26. Others have a more or less limited distribution, ranging to those known from a single district or even a single station.

The various taxa are arranged alphabetically. In general, treatment follows that of the second edition of Hitchcock's *Manual of Grasses,* which can be consulted for descriptions. Names differing from those of the *Manual* are designated by an asterisk and may be found listed with the equated name at the end of the checklist proper. Taxa not included in the *Manual* are marked by a double asterisk, and are listed with easily available references for descriptions.

The author prefers a taxonomy which emphasizes similarities at least as much as differences. In general, he feels that too many genera and species of grasses have been segregated, rather than too few. Nevertheless, he has made no new combinations and has combined generally separated taxa only where he feels the evidence warrants it. This, admittedly, leads to some imbalance because of lack of knowledge in certain complexes.

Only major morphological races with incipient isolation are listed for a species. The author prefers to use subspecies for this category but, again, has made no new combinations, generally using variety, if this combination was available, or even species, where no infraspecific trinomial existed. In certain cases, particularly in *Panicum,* subg. *Dichanthelium,* he avoided too stringent reduction, because some of the varietal combinations already made have tended to obscure the position of the reduced species as intermediate between two groups. In this same subgenus, and in *Paspalum,* he accepted certain species to avoid inconsistent "speciation" within the genus and subgenus. In addition to the infraspecific races listed, a number of named minor variants have been collected in the State. A list of such variants is added at the end of the checklist, with cross-references to the species or major race to which they have been referred.

Several cases of hybridity have been noted or postulated. A list of recognized or suspected hybrids is appended. Many more are possibly present, particularly in *Panicum* and *Poa.*

As an indication of work yet to be done, attention is called to three of many problems. The author proposes to undertake detailed exploration for, and analysis of, *Calamagrostis,* subsect. *Ancylatherae.* Collections from the Taconics and Catskills here referred to *C. lacustris* are not typical nor do they exactly match each other or anything already described, although they approach *C. porteri perplexa.* Material of *C. lacustris* from woods in Essex County has sheath-collars as hairy as *C. porteri*; the same colony (clone ?) in the open has essentially glabrous collars. Further, the plants in the open show a tendency to " creep " in crevices and on ledges but tend to " tuft " like *C. fernaldii* in hollows. The relationship of our representatives to the midland *C. insperata* and to the *Ancylatheran* types of the West is problematical.

In *Poa,* it is obvious that there should be some subdivision in what the author has called *P. pratensis, P. palustris* and *P. compressa* — possibly also in *P. trivialis. Poa nemoralis* needs more study, although its limits may be confused by hybridity. The possibility of the relationship of *P. interior* to *P. glauca,* rather than to *P. nemoralis,* should be considered. *Poa languida* and *P. saltuensis* are a difficult pair. Finally, there are apparent hybrid swarms at two of our stations for *P. glauca.*

In *Festuca,* the *F. rubra* complex is particularly baffling, apparently being an euploid series. There may be six races, instead of two, each with its own habitat-preference. The most distinctive is a shade-loving heterophyllous type, but it lacks the bristly tip to the ovary, required for *F. heterophylla* (*F. rubra,* var.). The dune-slack creeper is different from the sand-bar creeper. There are three types of tussock-formers. Poor collecting, particularly of basal parts, and inability to correlate the various European and American treatments forced the author to separate only the creepers and the tufters, as a provisional arrangement. In the *F. ovina* relationship, as here construed, *F. brachyphylla* is almost certainly distinct. If a second break is necessary, it should ally " tenuifolia " with " ovina " proper, and " saximontana " with " longifolia."

Finally, a list of desiderata has been prepared. This includes a number of native species and races, particularly of boreal-montane and Coastal Plain affinities. A number of introductions, established near our borders but not yet known from New York, are represented. To these has been added a considerable series of casuals, known from various parts of the Northeast.

During the 30 years of his scientific interest in the grasses of New York State, the author has received both assistance and advice from several teachers and colleagues. The late Dr. Karl M. Wiegand, as

Professor of Botany and Chairman of the Department of Botany at the New York State College of Agriculture of Cornell University, first suggested serious study of the family and gave constant encouragement and professional guidance until his retirement. Dr. Robert T. Clausen, Professor of Botany at the same college, has pointed out certain problems and helped mold the author's species-concept. Dr. Jason R. Swallen and the late Dr. Agnes Chase, both of the National Herbarium, Smithsonian Institution, Washington, D.C., have discussed many agrostological problems and identified or verified certain problem-specimens. The former kindly read the entire manuscript. Nevertheless, the author accepts full responsibility for errors or omissions.

Mr. Roy Latham, Orient, has presented his extensive herbarium of Long Island materials, including several hundred sheets of grasses, to the New York State Museum. Several species are known for the State only from his explorations and many others were first found by him. Mr. Theodore C. Baim, Schenectady; Mr. Karl Brooks, Brooklyn; Mrs. Mary Domville, Woodstock; Dr. Mildred E. Faust, Professor of Botany, Syracuse University; and Mr. Robert Meyer, Staten Island, have made their grass collections available. Each has contributed important records.

At various herbaria, the staffs have graciously made materials and facilities available to the author. For these courtesies he is most appreciative. Herbaria visited in this connection are: Wiegand Herbarium and Bailey Hortorium, State University College of Agriculture at Cornell University; State University College of Forestry at Syracuse University; New York Botanical Garden; Brooklyn Botanic Garden; College of Arts and Sciences, Syracuse University; Rochester Academy of Science; Buffalo Museum of Science; Staten Island Institute of Arts and Sciences; St. Bonaventure University; Elmira College; National Herbarium, Smithsonian Institution; Gray Herbarium, Harvard University. The late Dr. Homer D. House, former State Botanist, Dr. Eugene C. Ogden, currently in that position, and many other colleagues of the State Museum, have offered constant encouragement.

It can be seen that much remains to be done on the grasses. The wilder and less disturbed areas of our mountains and coastal plain are full of surprises. Nurseries, railroad yards and agricultural areas will surely produce many additions. Adequately labeled specimens (provided with collector's name, date of collection, locality and habitat) will be welcome. They may be mailed or brought to the State Museum for identification and record. Notice of omissions will be appreciated. If any botanists are encouraged to search for and collect grasses, then this checklist will have served its purpose.

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
GRAMINEAE																										
Aegilops																										
crassa Boiss.**																									x	
cylindrica Host													v					x						x	x	
ovata L.															x											
triuncialis L.																									x	
Agropyron																										
bonaepartis (Spreng.) Dur. & Schinz.**																									x	
cristatum (L.) Gaertn.																							v			
desertorum (Fisch.) Schult.		x																x								
orientale (L.) R. & S.**																									x	
pungens (Pers.) R. & S.																								x		
repens (L.) Beauv.	O	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
smithii Rydb.							x						x													
trachycaulum (Link) Malte, var. glaucum (Pease & Moore) Malte*	X	X	X	X	X	X			X	X	X		X	X	X		X	X	X	X					X	
var. novae-angliae (Scribn.) Fern.*	X	X	X	X		X			X	X	X				X			X			X					
trichophorum (Link) Richt.																									x	
triticeum Gaertn.																									x	
Agrostis																										
borealis Hartm.			H	X																						
canina L., ssp. canina																		X			O					
ssp. montana Hartm.*															X								X		?	X
gigantea Roth, var. dispar (Michx.) Philipson*	X	O	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Agrostis (*continued*)																										
gigantea Roth, var. gigantea*				X									X	X								X				X
hyemalis (Walt.) BSP.	X												x				x	x		X			X	X	X	
perennans (Walt.) Tuckerm., ssp. elata Hitchc.*																						X			X	X
ssp. perennans		X	X	X	X	L	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X
scabra Willd.	X	X	X	X	L	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X
semiverticillata (Forsk.) C. Christ.																									v	
spica-venti L.*																		x						x	x	
stolonifera L., var. palustris (Huds.) Farw.*				X		X				X		X		X	X			X								
var. stolonifera*	O	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X
tenuis Sibth.			X	X			X	X	X	X	X	O	X		X	X	X	X	X	X	O	X	X		X	X
Aira																										
caryophyllea L.																						X	X		X	X
praecox L.																										X
Alopecurus																										
aequalis Sobol., ssp. aequalis	X	X		X		X	X	X	X	L	X	X	X	X	X	X	X	X			X	X		X		X
carolinianus Walt.																		x							x	
geniculatus L.		X							X						X			X							X	
myosuroides Huds.															x			x							x	
pratensis L., ssp. pratensis				X		O	X		X	X	X	X	X		X		X	X			X	L		X	X	
Ammophila																										
breviligulata Fern.				X			X	X				X	X									X	X	X	X	X

	DISTRICTS (See Map)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Andropogon																										
gerardii Vitm.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ischaemum L.																									x	
scoparius Michx., var. littoralis (Nash) Hitchc.*																						X	X	X	X	
var. scoparius			X	X	L	L	X	X	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X
virginicus L., var. abbreviatus (Hack.) Fern. & Grisc.*																						X	X	X	X	X
var. virginicus						X			X				X							L	X	X		X	X	X
Anthoxanthum																										
aristatum Boiss.							x								x											
odoratum L.		X	X	X		H	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Aristida																										
adscensionis L.																									x	
basiramea Engelm.			X	X				X	X																	
dichotoma Michx.									X	X	X		X		X		X	X	X	X	X	X		X	X	X
longespica Poir.																						X	X	X	X	X
oligantha Michx.							X		X		X			X	X			X			X			X	X	X
purpurascens Poir.																					X	X	X	X	X	X
tuberculosa Nutt.															x						X			X	X	X
Arrhenatherum																										
elatius (L.) Presl, ssp. elatius				O	O	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X
Arthraxon																										
hispidus (Thumb.) Makino																									x	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Avena																										
fatua L., ssp. fatua			x					x					x		x	x	x	x							x	
ssp. sativa (L.) Thell.*			x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	o	o	x		x	x	
Beckmannia																										
eruciformis (L.) Host, ssp. baicalensis (Kusn.) Hultén*							X						x		x										x	
Bouteloua																										
curtipendula (Michx.) Torr., var. curtipendula							L										X	X		X	X					X
gracilis (HBK.) Lag.							x																			
Brachyelytrum																										
erectum (Schreb.) Beauv.		X	X	X	H	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X				X	
Briza																										
maxima L.																						x			x	
media L.									X						X	X					L					
minor L.																									v	
Bromus																										
arvensis L.														X	x			x								
briziformis Fisch & Mey.															x			x				x				
carinatus Hook & Arn.													x													
ciliatus L.		X	X	X	H	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			L	X	
commutatus Schrad.		O			L	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
diandrus Roth*																						X				X
erectus Huds.															X					O		X			X	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Bromus (*continued*)																										
inermis Leyss., ssp. inermis		O	X	X	O	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X		X	X	X	X
japonicus Thunb.					O	X	X	X				X	X	X	X		X	X		X		X		X	X	X
kalmii Gray		X		X		H	X	X	X		X		X	X	X		X	X			X					
lepidus Holmb.**																									x	
macrostachys Desf.																									x	
marginatus Nees.							x																			
mollis L.			X			X	X						X	X	X	X	X	X			X	X	X	L	X	X
pubescens Muhl.*		X		O	X	O	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
purgans L.*				X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X				X	
racemosus L.					l										x									h		
rubens L.															x											
scoparius L.																									x	
secalinus L.		X	X		L	X	X	X	X		X	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X
squarrosus L.																		X							x	
sterilis L.					X	H							X	X	X									X	X	L
tectorum L.		X	X		H	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
willdenowii Kunth*																		x								
Calamagrostis																										
canadensis (Michx.) Beauv., ssp. canadensis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ssp. langsdorfii (Link) Hultén*				X																						
cinnoides (Muhl.) Bart.																		L		X				X	X	X
epigeios (L.) Roth.													X					X			O				X	
inexpansa Gray							L							X	X										X	
lacustris (Kearney) Nash			X	X				X		X							X	X								

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Calamagrostis (*continued*)																										
neglecta (Ehrh.) Gaertn., Mey. & Scherb., ssp. neglecta											X															
pickeringii Gray			X	X						X															X	
porteri Gray, ssp. perplexa (Scribn.) Clausen*															X											
ssp. porteri														X	X											
Calamovilfa																										
longifolia (Hook.) Scribn., var. magna Scribn. & Merr.													V													
Catapodium																										
rigidum (L.) C. E. Hubbard*							v																			
Cenchrus																										
biflorus Roxb.																									x	
longispinus (Hack.) Fern.*							X	X	X	X	X	X	X		X		X	X		X	X	X	X	X	X	X
tribuloides L.																		X				L		X	X	
Chloris																										
argentina (Hack.) Lillo & Parodi																									x	
ciliata Sw.																									x	
verticillata Nutt.															x											
virgata Sw.															x										x	
Cinna																										
arundinacea L.	H				H	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
latifolia (Trev.) Griseb.		X	X	X			H	X	X	X	X	O	X	X	X	X	X	X	X	X	L	X	X		X	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Coix																										
lacryma-jobi L.																									x	
Corynephorus																										
canescens (L.) Beauv.																									X	X
Cynodon																										
dactylon (L.) Pers.								X					X		X						X			X	X	X
Cynosurus																										
cristatus L.							X	X	X	X		X	X	X	X							X			X	
echinatus L.																									x	
Dactylis																										
glomerata L., ssp. aschersoniana (Graebn.) Thell.**							X	X							X										V	
ssp. glomerata	O	X	X	L	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dactyloctenium																										
aegyptium (L.) Beauv.																									x	
Danthonia																										
compressa Aust.		X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X		X	X
spicata (L.) Beauv.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Deschampsia																										
atropurpurea (Wahl.) Scheele, var. atropurpurea				X																						
caespitosa (L.) Beauv., var. caespitosa	L	X	X	X	L	X	X	X	X	X	X		H	L	X			X	X			X		X		
var. parviflora (Thuill.) Coss. & Germ.									X		X				X			X							X	X
danthonioides (Trin.) Munro															x											

	DISTRICTS (See Map)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Deschampsia (*continued*)																										
flexuosa (L.) Trin., var. flexuosa	X	X	X	X	L	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X
var. montana (L.) Huds.*				X																						
Digitaria																										
adscendens (H.B.K.) Henr.**																					x				x	
filiformis (L.) Koeler																				X	L	X		X	X	X
ischaemum (Schreb.) Schreb., var. ischaemum	X	X	X	X	L	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X		X	X	X
var. mississippiensis (Gatt.) Fern.																									X	
sanguinalis (L.) Scop.	O	X		X	L	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	V	X	X	X
Distichlis																										
spicata (L.) Greene, var. spicata																					X	X	X	X	X	X
Echinochloa																										
crusgalli (L.) Beauv., ssp. crusgalli	O	X	O	X	O	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	V	X	X	X
ssp. edulis Hitchc.*									x	x	x		x		x		x	x						x	x	x
muricata (Beauv.) Fern., var. microstachya Wieg.*	X		X	X		X	X	X	X	X	X	X	X	X	X		X			L				X	X	X
var. muricata*	X			X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	V	X	X	X
walteri (Pursh) Heller		X			X	X	X	X							X			X		X	X	X	X	X	X	X
Eleusine																										
indica (L.) Gaertn.					O		O	X	X		X	X	X	X	X	O	O	X	X	X	X	X		X	X	X
Elymus																										
arenarius L., ssp. arenarius**															x										X	
canadensis L.	X			X	X	X	X	X			X	X	X	X	X		O	X	O	X	X	X		X	X	
caput-medusae L.																									x	
glaucus Buckl., ssp. glaucus							x																			

	DISTRICTS (See Map)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Elymus (*continued*)																										
riparius Wieg.	O	X	X	X	X		X	X	X	X	X	O	X	X	X	X	X	X	X	X	X			X	X	
villosus Muhl.	X	X			X		L		X	X	X	L	X	X	X	X	X	X		X	X	X	X	X	X	X
virginicus L., var. glabriflorus (Vasey) Bush											X		X		X			X		X					X	X
var. halophilus (Bickn.) Wieg.																						X		X	X	X
var. virginicus	O	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	V	X	X	X
wiegandii Fern.*	X	X		X			X	X	X		X	O	X	X	X	X	X	X								
Eragrostis																										
capillaris (L.) Nees							L	X			X			X	X	X		X		X	X	X		X	X	X
cilianensis (All.) Link					O	X	X	X	X		X		X	X	X		X	X	X	X	X	X	V	X	X	X
curvula (Schrad.) Nees																						X			O	O
frankii C. A. Mey.						X		X	X	X	X	X	X	X	X			X			X					
hypnoides (Lam.) BSP.							X	X	X		X		X	H	X		X	X			X				X	
multicaulis Steud.		O		X		O		X	X		X		X	X	X	X	X	X	X	X	X				X	X
pectinacea (Michx.) Nees				X	H	X	X	X	X	HO	X	X	X	X	X	X	X	X	X	X	X	X	V	X	X	X
pilosa (L.) Beauv.							X						X	X	X			X		X	X	X		X	X	
pooides Beauv.	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		L	X	O
spectabilis (Pursh) Steud.		X					X	X	X	O	X			X	X		X	X		X	X	X	X	X	X	X
trichodes (Nutt.) Wood																		x								
Erianthus																										
giganteus (Walt.) Muhl.																									?	?
Eriochloa																										
gracilis (Fourn.) Hitchc.													x													
Festuca																										
arundinacea Schreb.		X		X	O	O		X		X	O		O		X		O	X		X		X		X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Festuca (*continued*)																										
brachyphylla Schultes*				X																						
bromoides L.*																									x	x
elatior L.	O	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X
gigantea (L.) Vill.																					X				X	
myuros L.																						X	X		X	X
obtusa Biehler	X	X	X	X	L	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X
octoflora Walt., ssp. octoflora							X		H			H	X	X	X		X	x		X	X	X	X	X	X	X
ovina L., ssp. longifolia (Thuill.) Gaudin*	X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X
ssp. ovina			X				X		X		X			X	X	X				X			X		X	
ssp. saximontana (Rydb.) St. Ives*			X	X																						
ssp. tenuifolia (Sibth.) Arcang.*				X			X	X	X	X	X		X		X	X	X	X			X	X	X	X	X	X
rubra L., ssp. commutata Gaudin			X	X	O		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
ssp. rubra	X		X					X			X		X		X		O			X		X	X	X		
Glyceria																										
acutiflora Torr.											X			X	X	X	X	X		X	X	X	X	X	X	X
borealis (Nash) Batchelder	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X		X	X					
canadensis (Michx.) Trin., var. canadensis		X	X	X			X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
var. laxa (Scribn.) Hitchc.																								X	X	X
declinata Brebiss.																									x	
fluitans (L.) R. Br.															X	X					X			X	X	
maxima (Hartm.) Holmb., ssp. grandis (Wats.) Hultén*	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	L	X			X	
ssp. maxima**																										X
melicaria (Michx.) Hubb.		O	X	X			X	X	X	X	X	H	X	X	X	X	X	X	X	X	X				X	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Glyceria (*continued*)																										
obtusa (Muhl.) Trin.																							X	X	X	X
septentrionalis Hitchc.						X	O	X	X		X	X	X	X	X	X		X			X	X	X	X	X	
striata (Lam.) Hitchc., ssp. striata	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Heleochloa																										
schoenoides (L.) Host																									x	
Hierochloe																										
alpina (Sw.) R. & S., var. alpina			H	X																						
odorata (L.) Beauv., ssp. odorata			X	X			X	X	X	X	X	X			X		X	X				X	X	X	X	X
Holcus																										
lanatus L., ssp. lanatus		X	X			O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
mollis L.									X			X					X			V				X		
Hordeum																										
jubatum L., ssp. breviaristatum Bowden*																									x	
ssp. jubatum	X	X	X	O	X	X	X	X		O	X	H	X	X	X	X	O	X		X	X	X	X	X	X	X
murinum L., ssp. leporinum (Link) Arcang.*															x										x	
pusillum Nutt.															x									x	x	
vulgare L.						x	x			x		x	x	x	x	x		x			o	x			x	
Hystrix																										
patula Moench	X	X		X	H	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X				X	
Koeleria																										
phleoides (Vill.) Pers.																									x	
pyramidata (Lam.) Domin*															X										x	X

	DISTRICTS (See Map)																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Leersia																										
oryzoides (L.) Sw.	X	X	X	X	H	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
virginica Willd.		X			L	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Leptochloa																										
fascicularis (Lam.) Gray, var. fascicularis													x													
var. maritima (Bickn.) Gl.*								X			x										X		X	X	X	X
Leptoloma																										
cognatum (Schult.) Chase				X			X	X	X		X			H				X		X					X	X
Lolium																										
multiflorum Lam.		X	O	X	X		X	X			X	O	X	X	X	X		X			V	X	X	X	X	X
perenne L.		X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	O	X	O	X	X	X
persicum Boiss. & Hohenh.															x			x								
temulentum L.					l		x			l	x		h		x			x						x	x	
Melica																										
altissima L.																									x	
Mibora																										
minima (L.) Desv.							x																			
Milium																										
effusum L.		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	V					X
Miscanthus																										
sacchariflorus (Maxim.) Hack.									X																	
sinensis Anderss.																						X		X	X	X
Molinia																										
caerulea (L.) Moench, var. caerulea										X											X				X	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Muhlenbergia																										
asperifolia (Nees & Mey.) Parodi								X																		
capillaris (Lam.) Trin.					L																					X
frondosa (Poir.) Fern.	O	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	V	X	X	X
glomerata (Willd.) Trin.		X	X	X	X	X	X	X	X	X	X	L	X	X	X	X	X	X	X	X	X				X	
mexicana (L.) Trin.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X		X	X	
schreberi Gmel.					O	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X		X	X	X
sobolifera (Muhl.) Trin.											X			H	X		O	X		X	X				X	
sylvatica Torr.						X	X	X	X	X	X	X	X	X	X		X	X	X	X	L				X	L
tenuiflora (Willd.) BSP.					L	X	X				X		X	H	X	X	X	X	X	X	X				X	
uniflora (Muhl.) Fern.		X	X	X				L	X	X	X									X	L	L			X	X
Nardus																										
stricta L.									X	X	X															
Oryzopsis																										
asperifolia Michx.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	X					
canadensis (Poir.) Torr.				X																						
pungens (Torr.) Hitchc.		X	X	X			X		X	X	X			X	X		X	X		X	X					
racemosa (Sm.) Ricker	X	X		X	X	X	X	X	X		X	L	X	X	X	X	X	X	X	X	X					
Panicum																										
aculeatum Hitchc. & Chase									X																X	
agrostoides Spreng., var. agrostoides		X						X	X	X	X	X			X			X	X	X	X	X	X	X	X	X
amarum Ell.																						X	X	X	X	X
anceps Michx., var. anceps																							X			
annulum Ashe																									X	
ashei Pearson								X	X				X		X					X	X	X		X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Panicum (*continued*)																										
auburne Ashe																							V		X	X
boreale Nash		X	X	X					X	X	X						X									
boscii Poir.															X					X	X	X	X	X	X	X
calliphyllum Ashe								X			X				X			X		X						
capillare L.	O	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
clandestinum L.		X	X	X	L		L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
columbianum Scribn.*	X	X		X			X	X	X	X	X	X			X	X		X		X		X	X		X	X
commonsianum Ashe, var. commonsianum*		X							X								X	X			X	X	X		X	X
commutatum Schult.							o						X		X									L	X	X
depauperatum Muhl.		X		X	L		X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X
dichotomiflorum Michx., var. dichotomiflorum					O	O	X	X	X		X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X
dichotomum L.*					X		X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
flexile (Gatt.) Scribn.	X	X	X			X					X				X	X				X						
gattingeri Nash	X	X		O	O			X	X		X	X	X	X	X	X	X	X	X	X	X				X	
implicatum Scribn.*	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
latifolium L.		X		X	H	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	
leibergii (Vasey) Scribn.															X											
lindheimeri Nash						X	X	X	X		X				X			X	X			X		X	X	X
linearifolium Scribn.*	X	X		X		X		X	X	X	X		X	X	X	X	X	X	X	X	X				X	
longifolium Torr., var. longifolium																						X		X	X	X
lucidum Ashe																									X	X
malacon Nash																										X
mattamuskeetense Ashe*						X	X	X	X					X								X		X	X	X
meridionale Ashe							V		X													X	X		X	X
microcarpon Muhl.																					L	X	X	X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Panicum (*continued*)																										
miliaceum L.		x		x	x		x		x				x	x	x		x	x		x		x		x	x	x
oligosanthes Schult., var. scribnerianum (Nash) Fern.*							X	X	X		X				X			X		X	X	X	X	X	X	X
philadelphicum Bernh., var. philadelphicum									X		X		X		X		X	X		X	X			X	X	
var. tuckermanii (Fern.) Stey. & Schmoll*	X	X		X				X	X		X		X		X	X	O	X	X	X					X	
polyanthes Schult.																						X	X	X	X	
recognitum Fern.																									X	
scoparium Lam.																						X		X	X	X
sphaerocarpon Ell.						X	X	X	X		X		X	X	X			X	X	X	X	X	X	X	X	X
spretum Schult.			X				L		X	X								L				X	X		X	X
stipitatum Nash																						X			X	
subvillosum Ashe		X	X						X						X							X			X	
verrucosum Muhl.																						X		X	X	X
villosissimum Nash.*							X	X	X				H	X	X			X				X	X	L	X	X
virgatum L., ssp. cubense (Griseb.) Hitchc.																						X			X	X
var. spissum Linder				X				X	X				X		X		X	X		O	X	X	X	X	X	X
ssp. virgatum						X	X	X	X		X	X	X		X			X		X						
wrightianum Scribn.																						X			X	X
xanthophysum Gray		X		X				X	X	X	X			L	X	X	X	X			L					
Pappophorum																										
bicolor Fourn.																									x	
mucronulatum Nees																									x	
Paspalum																										
ciliatifolium Michx.*															X			X	X	O	X	X	X	X	X	X
circulare Nash		X					X	X	X		X		X	X								L		X	X	

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Paspalum (*continued*)																										
debile Michx.																						X				
dilatatum Poir.																									X	
laeve Michx.*																									X	
psammophilum Nash																						X	X	X	X	X
setaceum Michx.							L													O	L	X	L	H	X	X
stramineum Nash																		X								
Pennisetum																										
alopecuroides (L.) Spreng.																									x	
ciliare (L.) Link																									x	
Phalaris																										
arundinacea L.	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	X	X	X
canariensis L.		x					x	x	x	x	x	x	x	x	x	x		x			x	x	x	x	x	
Phleum																										
arenarium L.																									x	
paniculatum Huds.																									x	
pratense L., ssp. pratense	O	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	V	X	X	X
Phragmites																										
communis Trin., ssp. berlandieri (Fourn.) Löve & Löve*	X	X	X	O	L	X	X	X	O	X	X		X	X	X	O	X	X		X	X	X	X	X	X	X
Poa																										
alsodes Gray		X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	
annua L.	O	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
bulbosa L.															X										X	X
compressa L.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Poa (*continued*)																										
cuspidata Nutt.																								X	X	
glauca Vahl				X																						
interior Rydb.			X	X																						
languida Hitchc.	O	X		X	X	X	X		X	X			X	X	X	O		X		X	X					
laxa Haenke, ssp. fernaldiana (Nannf.) Hylander*				X																						
nemoralis L.	O	X	X	X	O		X	X	X		X		X	X	X	O	X	X	O	X	X	X		L	X	X
paludigena Fern. & Wieg.							X	X	X						X										X	
palustris L.	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
pratensis L.	O	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
saltuensis Fern. & Wieg.		X	X	X		X	X	X	X	X	X	X	X		X	X	X	X		X						
sylvestris Gray							X						X	L	X											
trivialis L.		X		X	O		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Polypogon																										
interruptus HBK.																									x	
monspeliensis (L.) Desf.									x																x	
Puccinellia																										
distans (L.) Parl.							X	X		X	X				X		X							X	X	
fasciculata (Torr.) Bickn.																								X	X	
pallida (Torr.) Clausen*		X	X	X	L		L	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
rupestris (With.) Fern. & Weath.																									x	
Schizachne																										
purpurascens (Torr.) Swallen	X	X	X	X	L	X	L	X	X	X	X		X	O	X	X	X	X		X	L					

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Sclerochloa																										
dura (L.) Beauv.																									x	
Secale																										
cereale L.							x	x	x	o	x		x	o	x	o	x	x	x		x	x		x	x	x
Setaria																										
faberii Herrm.								X			X	O	X		X	X	O	X		X	X			X	X	X
geniculata (Lam.) Beauv.								L														X	X	X	X	X
italica (L.) Beauv.							x	x	x	x	x		x	x	x	x		x	x	x		x		x	x	x
lutescens Hubbard	O	X	X	X	O	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X	V	X	X	X
verticillata (L.) Beauv.					O	O	X	X	O				X	X	X		X	X		X	O	V		X	X	
viridis (L.) Beauv.	O	X	X	X	O	X	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	X		X	X	X
Sorghum																										
bicolor (L.) Moench*							x	x	x		x		x		x		o	x			x	x		x	x	
halepense (L.) Pers.																		X			X			X		
nutans (L.) Gray*		O		X	X	X	X	X	X	X	X	X	X	X	X		O	X	X	X	X	X	X	X	X	X
Spartina																										
alterniflora Loisel.																					X	X	X	X	X	X
cynosuroides (L.) Roth.																					X		V	X	X	X
patens (Ait.) Muhl.								X					X								X	X	X	X	X	X
pectinata Link	O	X	X	X	X	X	X	X	X	X	X		X	H	X		X	X	X	X	X	X	X	X	X	X
Sphenopholis																										
intermedia (Rydb.) Rydb.	X	X	X	X	L	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	L		X	X	
nitida (Biehler) Scribn.							X	X			X		X	X	X	L	X	X		X	X			X	X	
obtusata (Michx.) Scribn.							L		V				L	X	X	O		X			X	X		X	X	
pensilvanica (L.) Hitchc.*					?		X			L					L				X		L		X	X	X	X

	DISTRICTS (See·Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Sporobolus																										
airoides (Torr.) Torr.																									x	
asper (Michx.) Kunth, var. asper							X	X			X				X			X		X	X	X		X	X	X
clandestinus (Biehler) Hitchc.																									X	X
contractus Hitchc.																					h					
cryptandrus (Torr.) Gray, ssp. cryptandrus							x								x											
ssp. fuscicola (Hook.) Jones & Fassett*							X	X				X	X					X				X			X	V
heterolepis (Gray) Gray									X									X								
neglectus Nash		X		X		X	X	X		X	X		X	X	X	X	X	X			X		X	X	X	
poiretii (R. & S.) Hitchc.																									x	
pyramidatus (Lam.) Hitchc.																									x	
vaginiflorus (Torr.) Wood	O	X	X		O	X	X	X	X	X	X	O	X		X	X	X	X	X	X	X	L		X	X	O
Stipa																										
avenacea L.																		L			X	X	X	X	X·	X
comata Trin. & Rupr.							x																			
viridula Trin.							x																			
Tragus																										
berteronianus Schult.																									x	
racemosus (L.) All.																									x	
Trichloris																										
crinita (Lag.) Parodi																									x	
Tridens																										
flavus (L.) Hitchc.							X	X	X		X		X		X			X		X	X	X		X	X	X

	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Triplasis																										
purpurea (Walt.) Chapm.												X	X					X			X	X	V	X	X	X
Tripsacum																										
dactyloides (L.) L.																						X	X	X	X	X
Trisetum																										
flavescens (L.) Beauv.			x												x						x					
spicatum (L.) Richter, ssp. molle (Kunth) Piper		X	X	X			X	X	X	X	X						X	X	X	X						
ssp. pilosiglume (Fern.) Hultén*			X	X					?																	
Triticum																										
aestivum L.						o	x	x	x		x	x	x	x	x	o	x	x	x	x	o	x		x	x	
Uniola																										
laxa (L.) BSP.													?										X	X	X	
Zea																										
mays L.						x		x	x		o		o	o	x		x	o	o	o	x				x	x
Zizania																										
aquatica L., var. angustifolia Hitchc.	X	X	X	X				X		X	X			X	X	X		X								X
var. aquatica	X	X			X	X	X	X	X		X			X	X	X	X	X		X	X			L	X	X
var. interior Fassett											X										X				X	

REJICIENDAE

Reports of the following species and races for New York State could not be substantiated:

Agropyron trachycaulum, var. unilaterale (Cassidy) Malte*
Echinochloa colonum (L.) Link
Eleusine tristachya (Lam.) Lam.
Elymus arenarius, ssp. mollis (Trin.) Piper*
Glyceria striata, ssp. stricta (Scribn.) Hultén
Muhlenbergia torreyana (Schult.) Hitchc.
Panicum amarulum Hitchc. & Chase
P. roanokense Ashe
Poa chapmaniana Scribn.
Puccinellia nuttalliana (Schult.) Hitchc.*
P. pumila (Vasey) Hitchc.
Trisetum melicoides (Michx.) Scribn.

HYBRIDS

The following postulated hybrids have been collected in New York State:

Agrostis borealis x A. scabra (*A. x geminata* Trin.*)
A. canina x A. tenuis (*A. x canino-vulgaris* Mercier)
A. gigantea x A. stolonifera
A. gigantea x A. tenuis
Danthonia compressa x D. spicata (*D. x allenii* Aust.)
Elymus riparius x E. villosus
Festuca arundinacea x F. elatior (*F. x aschersoniana* Dörfl.)
F. elatior x Lolium perenne (*x Festulolium loliaceum* (Huds.) Fourn.)
Glyceria borealis x G. septentrionalis
G. canadensis x G. striata (*G. x ottawensis* Bowden)
G. melicaria x G. striata (*G. x gatineauensis* Bowden)
Panicum columbianum x P. depauperatum
P. columbianum x P. implicatum (*P. x albemarlense* Ashe)
P. columbianum x P. microcarpon
P. depauperatum x P. dichotomum (*P. x bicknellii* Nash)
P. implicatum x P. linearifolium
P. implicatum x P. microcarpon
P. implicatum x P. oligosanthes (*P. x scoparioides Ashe*)
Poa glauca x P. laxa (*P. x scopulorum* Butters & Abbe)

P. nemoralis x P. palustris
Spartina patens x S. pectinata (*S. x caespitosa* A. A. Eaton)
Sphenopholis intermedia x S. nitida

MINOR VARIANTS

Each of the following minor variants, known to be in New York State, is included under the species concerned, or its nominate race. For descriptions of such not included in Hitchcock's second edition, the standard floras by Fernald and Gleason should be consulted. In instances where these three works do not describe the variant, a reference is cited in parentheses after the name.

Agropyron repens, f. aristatum (Schum.) Holmb.
  var. pilosum Scribn.
  var. subulatum (Schreb.) Reich.
  var. vaillantianum (Wulf. & Schreb.) Reich.
  f. setiferum Fern.
  f. trichorrhachis Rohlena
Agrostis borealis, var. americana (Scribn.) Fern.
A. perennans, f. chaetophora Fern.
  var. aestivalis Vasey
A. scabra, f. tuckermanii Fern.
A. tenuis, var. aristata (Parnell) Druce
Andropogon scoparius, f. calvescens Fern.
  var. frequens F. T. Hubbard
  var. glaucescens House (House)
  var. polyclados Scribn. & Ball
  var. septentrionalis Fern. & Grisc.
  var. villosissimus Kearney
A. virginicus, var. tetrastachyus (Ell.) Hack.
Anthoxanthum odoratum, f. giganteum P. Junge
Aristida longespica, var. geniculata (Raf.) Fern.
Arrhenatherum elatius, var. biartistatum (Peterm.) Peterm.
  var. flavescens Nielsen
  var. piliferum Beck (Hegi)
Arthraxon hispidus, var. cryptatherus (Hack.) Honda
Brachyelytrum erectum, var. septentrionale Babel
Bromus ciliatus, var. intonsus Fern.
B. commutatus, var. apricorum Simonkai
B. erectus, var. villosus (M. & K.) A. & G. (Hegi)

B. inermis, var. aristatus Schur
  var. villosus (M. & K.) M. & K.
  f. bulbiferus Moore (Fernald, 1950b — as f. *proliferus*)
  var. divaricatus Rohlena
B. japonicus, var. porrectus Hack.
B. lepidus, f. lasiolepis Holmb. (Hylander)
B. macrostachys, f. lanuginosus (Poir.) Boiss. (Hylander)
B. mollis, var. leiostachys Hartm.
B. purgans, var. incanus Shear
B. secalinus, var. submuticus Reichb. (Hylander)
  var. velutinus (Schrad.) Koch
B. squarrosus, var. villosus Koch (Hylander)
B. tectorum, var. glabratus Spenner
Calamagrostis canadensis, var. macouniana (Vasey) Stebbins
C. epegeios, var. georgica (C. Koch) Ledeb.
Dactylis glomerata, var. ciliata Peterm.
Danthonia spicata, var. villosa Peck (Fernald, 1943)
  var. longipila, Scribn. & Merr.
Deschampsia caespitosa, var. glauca, *sensu* Fern.
Digitaria sanguinalis, var. ciliaris (Retz.) Parl.
Echinochloa crusgalli, var. aristata S. F. Gray (Fernald, 1950b —as f. *longiseta*)
  f. vittata Hubbard (House)
E. walteri, f. laevigata Wieg.
Elymus canadensis, var. glaucifolius (Muhl.) Torr.
E. villosus, f. arkansanus (Scribn. & Ball) Fern.
E. virginicus, var. intermedius (Vasey) Bush
  var. jejunus (Ramaley) Bush
E. wiegandii, f. calvescens Fern.
Eragrostis spectabilis, var. sparsihirsuta Farw.
Erianthus giganteus, var. compactus (Nash) Fern.
Eriochloa gracilis, var. minor (Vasey) Hitchc.
Festuca elatior, f. aristata Holmb.
F. octoflora, var. tenella (Willd.) Fern.
F. ovina, var. hispidula Hack.
F. rubra, var. subvillosa M. & K.
Hierochloe odorata, var. fragrans (Willd.) Richt. (Fernald, 1917)
  f. eamesii Fern.
Hordeum vulgare. var. trifurcatum (Schlecht.) Alef.
Hystrix patula, var. bigeloviana (Fern.) Deam
Leersia oryzoides, f. inclusa (Wiesb.) Dörfl.
  f. glabra A. A. Eaton

L. virginica, var. ovata (Poir.) Fern.
Lolium multiflorum, var. muticum DC. (Hylander)
  var. ramosum Guss.
L. perenne, var. cristatum Pers.
  var. orgyiale Döll. (Wiegand & Eames)
L. temulentum, var. leptochaeton A. Br.
Milium effusum, var. cisatlanticum Fern. (Fernald, 1950a)
Miscanthus sinensis, var. zebrinus Beal
Muhlenbergia frondosa, f. commutata (Scribn.) Fern.
M. glomerata, var. cinnoides (Link) F. J. Hermann
M. mexicana, f. ambigua (Torr.) Fern.
  f. setiglumis (S. Wats.) Fern.
M. sylvatica, f. attenuata (Scribn.) Palmer & Steyerm.
  var. robusta Fern.
Panicum boscii, var. molle (Vasey) Hitchc.
P. capillare, var. occidentale Rydb.
P. columbianum, var. oricola (Hitchc. & Chase) Fern.
  var. thinium (Hitchc. & Chase) Hitchc. & Chase
P. commonsianum, var. addisonii (Nash) Pohl
P. depauperatum, f. cryptostachys Fern.
  var. psilophyllum Fern.
P. dichotomiflorum, var. geniculatum (Wood) Fern.
P. dichotomiflorum, var. puritanoroum Svenson
P. dichotomum, var. barbulatum (Mx.) Wood
P. linearifolium, var. werneri (Scribn.) Fern.
P. mattamuskeetense, var. clutei (Nash) Fern.
P. villosissimum, var. pseudopubescens (Nash) Fern., *p.p.*
Paspalum laeve, var. pilosum Scribn.
Phalaris arundinacea, var. picta L.
Phleum pratense, f. viviparum (S. F. Gray) Louis-Marie
Poa annua, var. reptans Hausskn.
P. bulbosa, var. vivipara Koel. (Hylander)
P. compressa, var. silvestris Torr. (Wiegand & Eames)
P. pratensis, ssp. angustifolia (L.) Gaudin (Fernald, 1950b — as *P. angustifolia*)
P. saltuensis, var. microlepis Fern. & Wieg.
P. trivialis, subvar. semineutra Richt. (Hegi)
Puccinellia distans, var. angustifolia (Blytt) Holmb.
Schizachne purpurascens, f. albican (Fern.) Fern.
Setaria verticillata, var. ambigua (Guss.) Parl.
S. viridis, var. breviseta (Döll.) Hitchc.
  var. major (Gaudin) Posp. (Hylander)
  f. ramuliflora, D. N. Christiansen

Spartina alterniflora, var. glabra (Muhl.) Fern.
  var. pilosa (Merr.) Fern.
S. cynosuroides, var. polystachya (Mx.) Beal
S. patens, var. monogyna (M. A. Curt.) Fern.
S. pectinata, var. suttiei (Farw.) Fern.
Sphenopholis nitida, var. glabra (Nash) Scribn.
S. obtusata, var. lobata (Trin.) Scribn.
  var. pubescens (Scribn. & Merr.) Scribn.
Sporobolus vaginiflorus, var. inaequalis Fern.

Certain cultivated cereals (*Hordeum vulgare, Setaria italica, Sorghum bicolor, Triticum aestivum* and *Zea mays,* are represented by several subdivisions. These variations are not independently designated.

The following variants are referred as indicated:

Agropyron cristatiforme (Sarkar)	Agropyron cristatum
A. trachycaulum, var. trichocoleum (Piper) Malte (Fernald, 1933)	A. trachycaulum novae-angliae
Agrostis alba, f. aristigera (Fern.) Fern.	Agrostis gigantea dispar
A. peckii House (House)	A. scabra
Andropogon praematurus Fern.	Andropogon scoparius scoparius
Brachyelytrum aristosum, var. glabratum Vasey (Babel)	Brachyelytrum erectum
Bromus dudleyi Fern.	Bromus ciliatus
B. purgans, f. glabriflorus, Wieg.	B. pubescens
B. purgans, f. laevivaginatus, Wieg.	B. pubescens
Calamagrostis canadensis, var. robusta Vasey	transitional from *Calamagrostis canadensis canadensis* to *C. canadensis langsdorfii*
Elymus virginicus, var. australis (Scribn. & Ball) Hitchc.	Elymus virginicus glabriflorus
Eremopyrum bonaepartis, f. hirsutum (Spreng.) Bowden (Bowden, 1962)	Agropyron bonaepartis
Festuca ovina, var. villosa Schrad. (Hegi)	Festuca ovina longifolia

Glyceria nervata, var. parviflora Vasey (Wiegand & Eames)	Glyceria striata striata
G. pallida, var. fernaldii Hitchc.	Puccinellia pallida
Hierochloe nashii (Bickn.) Kaczmarek	Hierochloe odorata odorata
Panicum languidum Hitchc. & Chase	Panicum implicatum
P. lanuginosum, var. huachucae (Ashe) Hitchc. (Hitchcock — as *P. huachucae*)	P. implicatum
P. lanuginosum, var. fasciculatum (Torr.) Fern. (Hitchcock — as *P. huachucae*, var. *fasciculatum*)	P. implicatum
P. lanuginosum, var. septentrionale (Fern.) Fern. (Gleason)	P. implicatum
P. lanuginosum, var. tennesseense (Ashe) Gl. (Gleason)	P. implicatum
Paspalum pubescens, var. muhlenbergii (Nash) House (Gleason — *cf. P. muhlenbergii*)	P. ciliatifolium
Triodia flava, f. cuprea (Jacq.) Fosb. (Fernald, 1950b)	Tridens flava

	DISTRICTS (See Map)																									
DESIDERATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Agropyron intermedium (Host) Beauv.																										
A. trachycaulum, var. majus (Vasey) Fern.*																										
var. unilaterale (Cassidy) Malte*																										
Agrostis elliottiana Schult.																										
Aira elegans Willd.																										
Alopecurus creticus Trin.																										
A. rendlei Eig																										
Amphicarpum purshii Kunth																										
Andropogon elliottii Chapm.																										
A. ternarius Michx.																										
Aristida lanosa Muhl.																										
A. virgata Trin.																										
Arundinaria tecta (Walt.) Muhl.																										
Avena barbata Brot.																										
A. sterilis L.																										
Bouteloua radicosa (Fourn.) Griffiths																										
B. rigidiseta (Steud.) Hitchc.																										
Brachiaria plantaginea (Link) Hitchc.																										
Brachypodium distachyon (L.) Beauv.																										
Bromus arenarius Labill.																										
B. inermis, ssp. pumpellianus (Scribn.) Wagnon*																										
B. madritensis L.																										
B. rigidus Roth																										

	DISTRICTS (See Map)																									
DESIDERATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Calamovilfa brevipilis (Torr.) Scribn., var. brevipilis																										
Chloris gayana Kunth																										
Danthonia intermedia Vasey																										
D. sericea Nutt.																										
Digitaria serotina (Walt.) Michx.																										
D. violascens Link																										
Echinochloa colonum (L.) Link																										
Eleusine tristachya (Lam.) Lam.																										
Elymus arenarius L., ssp. mollis (Trin.) Piper*																										
Eragrostis ciliaris (L.) R. Br.																										
E. hirsuta (Michx.) Nees																										
E. intermedia Hitchc.																										
Erianthus alopecuroides (L.) Ell.																										
Festuca megalura Nutt.																										
F. paradoxa Desv.																										
F. rubra L., ssp. cryophila (Krecz. & Bobr.) Hultén*																										
F. sciurea Nutt.																										
Gastridium ventricosum (Gouan) Schinz & Thell.																										
Glyceria striata (Lam.) Hitchc., ssp. stricta (Scribn.) Hultén																										
Gymnopogon ambiguus (Michx.) BSP.																										
G. brevifolius Trin.																										

	DISTRICTS (See Map)																									
DESIDERATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Heleochloa alopecuroides (Pill. & Mitterp.) Host																										
Helictotrichon pubescens (Huds.) Pilger																										
Hordeum marinum Huds., ssp. gussoneanum (Parl.) Thell.*																										
H. marinum Huds., ssp. marinum																										
Lagurus ovatus L.																										
Leptochloa filiformis (Lam.) Beauv.																										
L. unimervia (Presl) Hitchc.																										
Manisuris rugosa (Nutt.) Kuntze																										
Microstegium vimineum (Trin.) A. Camus																										
Muhlenbergia curtisetosa (Scribn.) Bush																										
M. racemosa (Michx.) BSP.																										
M. richardsonis (Trin.) Rydb.																										
M. torreyana (Schult.) Hitchc.																										
Oryzopsis miliacea (L.) Benth. & Hook.																										
Panicum aciculare Desv.																										
P. adspersum Trin.																										
P. agrostoides Spreng., var. condensum (Nash) Fern.*																										
P. amarulum Hitchc. & Chase																										
P. angustifolium Ell.																										
P. benneri Fern.																										
P. caerulescens Hack.																										

	DISTRICTS (See Map)																									
DESIDERATA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Panicum commonsianum, var. euchlamydeum (Shinners) Pohl*																										
P. ensifolium Baldw.																										
P. hemitomon Schult.																										
P. hirstii Swallen**																										
P. lanuginosum Ell.																										
P. leucothrix Nash																										
P. longiligulatum Nash																										
P. nitidum Lam.																										
P. roanokense Ashe																										
P. scabriusculum Ell.																										
P. trifolium Nash																										
P. yadkinense Ashe																										
Parapholis incurva (L.) C. E. Hubbard																										
Paspalum boscianum Flügge																										
P. difforme LeConte																										
P. dissectum (L.) L.																										
P. floridanum Michx.																										
P. notatum Flügge																										
P. scrobiculatum L.																										
Phalaris minor Retz.																										
P. paradoxa L.																										
Phleum alpinum L., ssp. commutatum Gaudin*																										
P. pratense L., ssp. nodosum (L.) Trab.**																										

DESIDERATA	DISTRICTS (See Map)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Phleum subulatum (Savi) A. & G.																										
Poa alpigena (Fr.) Lindm.**																										
P. alpina L.																										
P. arctica R. Br.																										
P. autumnalis Muhl.																										
P. canbyi (Scribn.) Piper																										
P. chapmaniana Scribn.																										
P. glaucantha Gaudin																										
Puccinellia americana Sörensen*																										
P. nuttalliana (Schult.) Hitchc.*																										
P. pumila (Vasey) Hitchc.																										
Sacciolepis striata (L.) Nash																										
Setaria magna Griseb.																										
S. setosa (Swartz) Beauv.																										
Trisetum aureum (Ten.) Ten.																										
T. melicoides (Michx.) Scribn.																										
Uniola latifolia Michx.																										

ADDITIONS 1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26

ADDITIONS	1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26

Synonymy

No equation is indicated here, when the change is merely one of rank below the level of species, without any change in infraspecific epithet.

CHECKLIST NAME	MANUAL NAME
Agropyron trachycaulum, *p. p.*	Agropyron subsecundum
Agrostis x geminata	Agrostis scabra, var. geminata
A. gigantea, var. dispar	A. alba
A. gigantea, var. gigantea	A. nigra
A. perennans, ssp. elata	A. altissima
A. spica-venti	Apera spica-venti
A. stolonifera, var. palustris	Agrostis stolonifera
A. stolonifera, var. stolonifera	A. palustris
Andropogon scoparius, var. littoralis	Andropogon littoralis
A. virginicus var. abbreviatus	A. glomeratus, *p. p.*
Avena fatua, ssp. sativa	Avena sativa
Beckmannia eruciformis, ssp. baicalensis	Beckmannia syzigachne
Bromus diandrus	Bromus rigidus, var. gussonei
B. inermis, ssp. pumpellianus	B. pumpellianus
B. pubescens	B. purgans
B. purgans	B. latiglumis
B. willdenowii	B. catharticus
Calamagrostis canadensis, ssp. langsdorfii	Calamagrostis canadensis, var. scabra
C. porteri, ssp. perplexa	C. perplexa
Catapodium rigidum	Scleropoa rigida

CHECKLIST NAME	MANUAL NAME
Cenchrus longispinus	Cenchrus pauciflorus
Digitaria adscendens	Digitaria sanguinalis, *p. p.*
Echinochloa crusgalli, ssp. edulis	Echinochloa crusgalli, var. frumentacea
E. muricata	E. crusgalli, *p. p.*
Elymus arenarius, ssp. mollis	Elymus mollis
E. wiegandii	E. canadensis, *p. p.*
Festuca brachyphylla	Festuca ovina, var. brachyphylla, *p. p.*
F. bromoides	F. dertonensis
F. ovina, ssp. longifolia	F. ovina, var. duriuscula
F. ovina, ssp. saximontana	F. ovina, *p. p.,* incl. var. brachyphylla, *p. p.*
F. ovina, ssp. tenuifolia	F. capillata
F. rubra, ssp cryophila	F. rubra, *p. p.,* incl. var. prolifera
Glyceria maxima, ssp. grandis	Glyceria grandis
Hordeum jubatum, ssp. breviaristatum	Hordeum brachyantherum
H. marinum, ssp. gussoneanum	H. hystrix
H. murinum, ssp. leporinum	H. leporinum
Koeleria pyramidata	Koeleria cristata
Panicum agrostoides, var. condensum	Panicum condensum
P. columbianum, *p. p.*	P. oricola
P. columbianum, *p. p.*	P. tsugetorum
P. commonsianum, var. commonsianum, *p. p.*	P. addisonii
P. commonsianum, var. euchlamydeum	P. pseudopubescens, *p. p.*
P. dichotomum, *p. p.*	P. barbulatum
P. implicatum, *p. p.*	P. huachucae
P. implicatum, *p. p.*	P. languidum
P. implicatum, *p. p.*	P. tennesseense
P. linearifolium, *p. p.*	P. werneri
P. mattamuskeetense, *p. p.*	P. clutei
P. oligosanthes, var. scribnerianum	P. scribnerianum
P. philadelphicum, var. tuckermanii	P. tuckermani
P. villosissimum, *p. p.*	P. pseudopubescens, *p. p.*
Paspalum ciliatifolium, *p. p.*	Paspalum pubescens

CHECKLIST NAME	MANUAL NAME
P. laeve, *p. p.*	P. longipilum
Phleum alpinum, ssp. commutatum	Phleum alpinum
Phragmites communis, ssp. berlandieri	Phragmites communis
Poa laxa, ssp. fernaldiana	Poa fernaldiana
Puccinellia americana	Puccinellia maritima
P. nuttalliana	P. airoides
P. pallida, *p. p.*	Glyceria fernaldii
P. pallida, *p. p.*	G. pallida
Sorghum bicolor, *p. p.*	Sorghum sudanense
S. bicolor, *p. p.*	S. vulgare
S. nutans	Sorghastrum nutans
Sphenopholis pensilvanica	Trisetum pennsylvanicum

References for Descriptions

The following species and subspecies are not included in Hitchcock's *Manual,* ed. 2. References for descriptions are indicated in parentheses after the name.

Aegilops crassa (Gleason)
Agropyron bonaepartis (Gleason — as *A. squarrosum*)
A. orientale (Gleason)
Bromus lepidus (Hubbard)
Dactylis glomerata, ssp. aschersoniana (Hubbard — as *D. polygama*)
Elymus arenarius, ssp. arenarius (Bowden, 1957)
Glyceria maxima, ssp. maxima (Fernald, 1950b — as *G. spectabilis*)
Panicum hirstii (Swallen)
Poa alpigena (Fernald, 1950b)

For species and races subdivided differently from the treatment in the *Manual of Grasses,* the following references are given:

Agropyron trachycaulum (Fernald, 1950b)
Agrostis canina (Hubbard)
A. gigantea (Philipson)
A. stolonifera (Philipson)
Andropogon virginicus & A. glomeratus (Fernald, 1950b)
Deschampsia flexuosa (Fernald, 1950b)
Digtitaria sanguinalis & D. adscendens (Ebinger)
Echinochloa crusgalli & E. muricata (Wiegand & Eames)
Elymus canadensis & E. wiegandii (Fernald, 1950b)
Festuca ovina & F. brachyphylla (Gleason, as *F. ovina,* vars.)
F. rubra (Fernald, 1950b — as *F. rubra* & *F. prolifera*)
Glyceria striata (Fernald, 1950b)
Leptochloa fascicularis (Gleason)
Panicum commonsianum (Pohl)
P. lanuginosum (Gleason)
Phleum pratense (Fernald, 1950b)
Sporobolus cryptandrus (Jones & Fassett)
Trisetum spicatum (Hultén)

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Stratigraphy of the Lockport Formation (Middle Silurian) in New York State

Donald H. Zenger
Temporary Geologist
New York State Museum and
Science Service
Geological Survey

BULLETIN NUMBER 404

NEW YORK STATE MUSEUM AND
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Contents

PAGE

1 **ABSTRACT**
3 **INTRODUCTION**
3 **General Statement**
5 **Objectives of the Investigation**
6 **Methods of Investigation**
7 **General Plan**
8 **ACKNOWLEDGMENTS**
11 **PREVIOUS WORK AND NOMENCLATURAL HISTORY**
30 **STRUCTURAL GEOLOGY**
33 **STRATIGRAPHY**
33 **Regional**
33 **Stratigraphic Nomenclature**
34 **Thickness**
37 **Stratigraphy of the Western Area**
37 *General*
38 *DeCew Member*
47 *Gasport Member*
57 *Limestone "lentil"*
60 *Goat Island Member*
64 *Eramosa Member*
66 *Oak Orchard Member*
72 **Stratigraphy of the West-Central Area**
72 *General*
72 *DeCew Member*
75 *Penfield Member*
82 *Oak Orchard Member*

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PAGE

88 **Stratigraphy of the East-Central Area**
88 *General*
88 *Sconondoa Member*
89 *Limestone Facies*
93 *Dolomite Facies*
98 **Stratigraphy of the Eastern Area**
98 *General*
98 *Ilion Member*
109 **SPECIAL FEATURES**
109 **Bioherms and Biostromes**
113 **Stromatolites**
120 **Dolomitization**
128 **EQUIVALENCE AND CORRELATION**
128 **Western and Central New York**
128 *Previous Attempts*
129 *Proposed Relationships*
132 **Eastern North America**
134 **Type Section (England)**
135 **PALEOECOLOGICAL AND PALEOGEOGRAPHICAL CONSIDERATIONS**
135 **Depositional Environment**
135 *Underlying and Overlying Units*
135 *Lockport Formation*
140 **Provenance**
144 **ECONOMIC ASPECTS**
149 **APPENDIX I. LOCATION OF SECTIONS AND OUTCROPS**
162 **APPENDIX II. DESCRIPTION OF SELECTED SECTIONS**
196 **APPENDIX III. COMMENTS ON SYSTEMATIC PALEONTOLOGY**
200 **BIBLIOGRAPHY**

Illustrations

PAGE

FIGURE 1. Outcrop belt of Lockport Formation 4

FIGURE 2. Vertical joints in Gasport Member 31

FIGURE 3. Classification of Lockport Formation 35

FIGURE 4. Columnar section of Lockport Formation in Niagara Falls area 39

FIGURE 5. Lower Lockport at Niagara Power Project 40

FIGURE 6. Enterolithic structure in lower DeCew at Concrete Materials quarry, Bergen quadrangle 41

FIGURE 7. Rochester, DeCew, and Gasport in roadcut south of Hickory Corners 44

FIGURE 8. Photomicrograph of corrosion surface between DeCew and Gasport Members 45

FIGURE 9. Photomicrograph of lower crinoidal Gasport Member 49

FIGURE 10. DeCew-limestone "lentil" sequence at type section of "lentil" southeast of Brockport 58

FIGURE 11. Photomicrograph of fine-grained Eramosa Member at Niagara Falls 65

FIGURE 12. Photomicrograph of Lower Oak Orchard Member at Niagara Falls 69

FIGURE 13. Columnar section of Lockport in Rochester-Penfield area 74

FIGURE 14. Gates, DeCew, and lower Penfield at Gates quarry 76

FIGURE 15. Stromatolite heads and associated edgewise conglomerate in limestone facies along Sconondoa Creek 91

PAGE

FIGURE 16. Photomicrograph. Ostracoda *Eukloedenella* in pellet-rich specimen of limestone facies of Sconondoa Member 92

FIGURE 17. Columnar section of Ilion Member near Clinton 99

FIGURE 18. Interfingering of Ilion shale and stromatolite limestone of Sconondoa Member along Sconondoa Creek at Sherrill 100

FIGURE 19. Structureless limestone bioherm in Gasport Member 2 miles west of Lockport 108

FIGURE 20. Lens-shaped, dolomitized bioherm in Gasport Member at Royalton quarry, Gasport 110

FIGURE 21. Close-up of bioherm in figure 20 111

FIGURE 22. Upper zone of stromatolites in Oak Orchard Member at Niagara Falls 114

FIGURE 23. Hemispherical domes in limestone facies of Sconondoa Member along Sconondoa Creek east of Vernon 116

FIGURE 24. Stromatolitic forms and structures 117

FIGURE 25. Photomicrograph. Relict oolites in dolomite of Sconondoa Member 122

FIGURE 26. Photomicrograph. Ostracode *Eukloedenella* in dolomitic limestone of Sconondoa; note replacement relations of dolomite rhombs 123

FIGURE 27. Triangular diagram showing composition of 58 Lockport samples with respect to calcite, dolomite, and insoluble residue 125

FIGURE 28. High-insoluble and low-insoluble members of Lockport 141

FIGURE 29. Location of Lockport sections in and near Niagara Power Project 150

PLATE I. Stratigraphic section of Lockport Formation *Inside Back Cover*

Tables

PAGE

TABLE 1. Summary of Lockport nomenclature 22

TABLE 2. Distribution of Gasport fossils 53

TABLE 3. Distribution of Penfield fossils 80

TABLE 4. Distribution of Oak Orchard fossils 86

TABLE 5. Distribution of Sconondoa fossils 96

TABLE 6. Distribution of Ilion fossils 106

TABLE 7. Classification of bedding for report 162

TABLE 8. Classification of sedimentary rocks for report 163

Stratigraphy of the Lockport Formation (Middle Silurian) in New York State

by Donald H. Zenger[1]

ABSTRACT

THE LOCKPORT FORMATION (Middle Silurian) in New York State is the eastern extension of the thicker Niagaran carbonate sequence of the Indiana-Illinois region. In New York, the outcrop belt extends from Niagara Falls 200 miles eastward to Ilion, where it pinches out. The Lockport, underlain by the Clinton Group and overlain by the Salina Group, is considered a formation generally characterized by brownish-gray color, medium granularity, medium to thick bedding, stylolites, carbonaceous partings, vugs, and poorly preserved fossils. Vertical and lateral differences permit the recognition of members. Apparently there are no important stratigraphic breaks within or bounding the formation.

At Niagara Falls, where the Lockport is 200 feet thick, it comprises five members in vertical sequence. The DeCew, included in the Lockport as its basal member, is fine-grained, " enterolithic," argillaceous dolomite. Overlying the DeCew is the Gasport Member, consisting of coarse-grained, crinoidal dolomite and dolomitic limestones that contain bioherms and biostromes. Brachiopods, corals, bryozoans, and stromatoporoids are abundant. Farther east, in the Bergen quadrangle, the stratigraphic position of the Gasport is occupied by fine-grained, fossiliferous, (brachiopods, trilobites) limestone named informally the " limestone lentil of the Lockport Formation at Brockport." The Goat Island, conformably overlying the Gasport, is saccharoidal, low-insoluble dolomite in turn overlain by the fine-grained, thin-

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[1] Present address: Department of Geology, Pomona College, Claremont, Calif. Manuscript submitted for publication, October 28, 1963.

bedded, high-insoluble Eramosa. The upper part of the Lockport, the Oak Orchard Member, is saccharoidal, bituminous, low-insoluble dolomite. Stromatolites, corals, and stromatoporoids are fairly common. Just east of Niagara Falls, chert is present in the lower part of the Oak Orchard. Although the member is equivalent to the Guelph of Ontario, the typical Guelph lithology is absent in New York.

In the Rochester area, the Lockport is about 180 feet thick and consists of three members: in ascending order, the DeCew, Penfield, and Oak Orchard. The Penfield is a 60-foot unit roughly equivalent to the Gasport, Goat Island, and Eramosa Members to the west. It is characterized by a high quartz content and crinoidal zones.

The entire Lockport sequence between Clyde and Oneida is considered a member, the Sconondoa, consisting of a dark-gray, fine-grained limestone facies and a medium-gray, sparkling dolomite facies. The most common fossils in both facies are stromatolites, *Eukloedenella, Herrmannina, Howellella,* and *Pterinea.* The member is about 150 feet thick at Clyde and 75 feet thick at Oneida.

The Ilion Member, 0–70 feet thick, represents the Lockport in the Rome, Utica, and Winfield quadrangles. The unit consists of dark, fissile shale, dolomitic shale, and stromatolitic dolomite. Linguloids are the dominant faunal element. The easternmost sections contain intercalations of the underlying Herkimer (Clinton) quartzite. East of the Winfield quadrangle, the Ilion is absent but is believed to be partly represented by the upper Herkimer and partly by the Herkimer-Salina disconformity.

Lithologic and fossil evidence strongly suggest that the Oak Orchard, Sconondoa, and Ilion Members are at once equivalents and correlatives. These members contain a common assemblage of fossils and are herein designated the *Herrmannina-Howellella-Pterinea* Assemblage Zone of the Lockport Formation of New York.

Dolomitized structures, such as bioherms, biostromes, stromatolites, oolites, and pellets, indicate a replacement origin for the dolomites.

Most of the Lockport sediments accumulated in an environment characterized generally by warm, shallow water, above-normal salinity, high pH (8–9), and reducing conditions. Although the source of terrigenous material for the Ilion was from the east, the northern shoreline exerted a greater influence on Lockport sedimentation west of Oneida.

Introduction

GENERAL STATEMENT

The Silurian Lockport Dolomite of New York State is the eastern extension of the thicker Niagaran limestone and dolomite sequence of the Great Lakes mid-continent region. These carbonates, more resistant than the underlying units, form the conspicuous Niagara Escarpment that can be traced continuously from the Manitoulin Islands north of Lake Huron, across southern Ontario, and into western New York as far east as Rochester. From Hamilton, Ontario, westward to Wisconsin, the strike of the Silurian rocks is concentric to the Michigan Basin. In the Niagara Peninsula, east of Hamilton, and in New York State, the strike is east-west and the dip is south toward the Appalachian Basin.

In New York, the outcrop belt of the Lockport extends from Niagara Falls 200 miles eastward to Ilion (Winfield quadrangle), where it pinches out (see figure 1). The greater part of the belt, from Niagara Falls to Oneida, lies in the Eastern Lake Section of Fenneman (1946). The Niagara Escarpment, along which are many outcrops of the lower Lockport, is not a recognizable feature east of Rochester. Relief is minimal for some distance

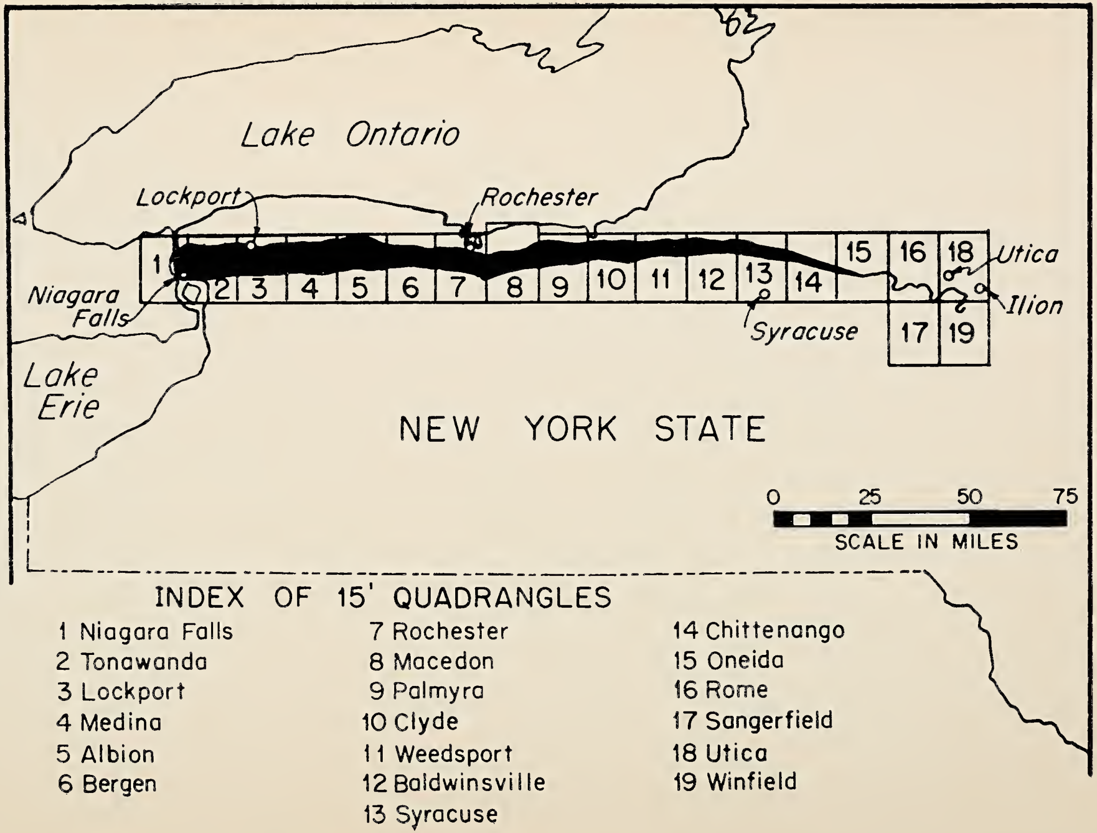

FIGURE 1. — Outcrop belt of Lockport Formation.

south of the escarpment, and natural exposures are rare due to the cover of glacial drift, which consists largely of Pleistocene lake sediments. East of Rochester, as far as Baldwinsville, drumlins conceal most of the bedrock. In the easternmost quadrangles containing the outcrop belt (Rome, Utica, and Winfield), exposures of the Lockport are numerous because of the more rugged topography of the northern edge of the Appalachian Plateau province (Fenneman, 1946).

OBJECTIVES OF THE INVESTIGATION

Most of the previous work on the Lockport has been done in connection with the mapping of various quadrangles that include parts of the outcrop belt. The principal objective of this investigation is to examine in detail the stratigraphy of the formation in New York State. Associated with the overall goal are these specific aims:

(1) Consideration of the stratigraphic validity and usefulness of previously designated units within the Lockport Dolomite of western New York;

(2) Examination of the detailed stratigraphy of the Lockport in the area between Rochester and Oneida where little is known about the unit;

(3) Consideration of the purported equivalence of the Lockport Dolomite with the Ilion Shale, which lies in the stratigraphic position of the Lockport in the Rome, Utica, and Winfield quadrangles.

METHODS OF INVESTIGATION

The investigation was carried out primarily as a field study, although complemented by much work in the laboratory.

Because much of the previous work on the Lockport has been in the western part of the State, where the unit is better exposed, field work was begun there. Six months, mostly during the summers of 1960 and 1961, were spent tracing the Lockport across western and central New York to its easternmost exposure in Herkimer County. Outcrops and sections at 175 localities were examined and measured. Collections were made from fossiliferous localities, and the various lithologic units were sampled. In October 1960, 3 days were spent studying the Lockport and Guelph Formations of southern Ontario in an attempt to understand better the stratigraphic relations between the New York sections and those to the west.

In the laboratory, the following studies were conducted:

(1) Examination of diamond drill cores from seven holes drilled between the longitudes of Niagara Falls and Sodus (Palmyra quadrangle);

(2) Petrographic analysis of thin sections of 41 specimens;

(3) Acidization of more than 100 selected samples in a quantitative insoluble residue study;

(4) X-ray diffraction analyses of 58 samples to determine the mineralogical composition, especially the calcite-dolomite ratios;

(5) Detailed study of fossils that could not be identified in the field.

GENERAL PLAN

For convenience in discussing the stratigraphy, the outcrop belt is divided arbitrarily into four geographic areas of different sizes, as follows:

(1) Western area — Niagara Falls through Bergen quadrangles;
(2) West-central area — Rochester through Palmyra quadrangles;
(3) East-central area — Clyde through Oneida quadrangles;
(4) Eastern area — Rome, Utica, and Winfield quadrangles.

Locations of outcrops and detailed descriptions of selected sections are given in Appendices I and II, respectively. All locality numbers given in the report refer to those in the appendix. Descriptive terms, such as bedding, texture, and color, as used in this report, are defined in the introductory material preceding the list of sections. The reader is urged to turn to this section for the meaning of terms as used herein.

Acknowledgments

Many people have contributed to the development of this report, but the writer assumes sole responsibility for the conclusions drawn.

Financial support for much of the summer field work in 1960 and 1961 was received from the New York State Museum and Science Service. Additional aid was provided by the Gurley Fund of the Department of Geology, Cornell University.

The writer is very grateful for suggestions and criticisms by Professors John W. Wells and Arthur L. Bloom, Cornell University. Thanks are extended to the several geologists who accompanied the writer in the field, including Professor Joseph St. Jean, Jr., and John Warren, University of North Carolina; Professor Robert G. Sutton, University of Rochester; Drs. Donald W. Fisher and Lawrence V. Rickard, New York State Geological Survey; and William Kilgour, Sanborn, N.Y.

The paleontologic aspects of the report have benefited from discussions with and identifications by other workers. The stromatolites were discussed with Professor John Kingsbury, Botany Department, Cornell University, and Professor J. Harlan Johnson, Colorado School of Mines. Dr. Jean M. Berdan, of the U.S. Geo-

logical Survey, identified many of the ostracodes. Professor Arthur J. Boucot, California Institute of Technology, examined specimens of *Howellella* and greatly helped the writer on other problems connected with the Lockport brachiopods. Some trilobite identifications were checked by Professor H. B. Whittington, Harvard University. Pelecypod specimens belonging to the genus *Pterinea* were commented on by Professor N. D. Newell, Columbia University, and Dr. Thomas E. Bolton, Canadian Geological Survey. John Warren, University of North Carolina, made several valuable suggestions concerning stromatoporoid identifications.

Thanks are due all the officials of the quarries now operating in the Lockport Formation. Without their cooperation, the field work would have been greatly impeded. The writer wishes to pay special appreciation to Charles Benziger, Project Geologist for the Niagara Power Project, and to the rest of the geology staff of Uhl, Hall, and Rich, engineers. They spared no efforts in enabling the writer to make as complete an examination of the Lockport as possible in the restricted power project excavations.

A brief investigation of the Lockport and Guelph Formations of the southern part of the Ontario Peninsula was made possible by Dr. Thomas E. Bolton, who pinpointed key sections for study. The Hydro-Electric Power Commission of Ontario granted permission to examine the section at DeCew Falls.

Richard Runvik, United States Gypsum Company at Oakfield, made available diamond drill cores from the Oakfield area. He generously gave the location of several Lockport and Salina outcrops in the

Albion and Medina quadrangles. William Brodie, New York Soils Laboratory at Hamburg, N.Y., provided two short cores of the uppermost Lockport from the Tonawanda and Lockport quadrangles. The Dolomite Products Company, Rochester, permitted the writer to study a test core for a new quarry to be located in the Ontario 7½-minute quadrangle. Cores in and adjacent to the Sodus quarry were studied through the courtesy of the General Crushed Stone Company.

The writer is indebted to Clinton F. Kilfoyle, New York State Museum at Albany, for locating and sending certain type specimens of Clarke and Ruedemann (1903) and Ruedemann (1916) for study purposes.

Two manuscripts in preparation for publication were made available: Dr. William A. Oliver, Jr., U.S. Geological Survey, on some Lockport corals; and Drs. A. J. Boucot and W. B. N. Berry, University of California (Berkeley), on Silurian correlations.

The writer is grateful to his wife, Ann, for assisting in editing the manuscript and to Shirley Bolton for typing the final draft.

Previous Work and Nomenclatural History

Table 1 (end of chapter) summarizes the history of Lockport nomenclature. It is not a correlation chart, and is intended only to show the nomenclature used by an author for the rocks within the Lockport sequence in a particular geographic area. The table is organized to read from older units on the left to younger on the right. Larger stratigraphic subdivisions (e.g., series) are given if an author has designated them, and although not shown in the table, they may include more than the Lockport. An asterisk indicates that a certain unit, currently used in connection with the Lockport, has been named and given a type section by a particular author.

An exhaustive review of all previous work on the Lockport Formation in New York is impractical. However, there is no recent synthesis of the important steps in the development of Lockport terminology, and a summary is appropriate.

The early settlers of western and west-central New York recognized the economic value of the Lockport before any geological studies were made. The dolomite was burned for lime, and the crinoidal beds in the lower part of the unit west of Rochester were quarried for use as ornamental and building stone. The basal beds of the Lockport, now known as the DeCew Dolomite, were found to possess the qualities of a waterlime and were used to make cement for the masonry on the Erie Canal.

Amos Eaton (1824, pp. 24, 37, 132) first described the Lockport of western New York, referring to it as the " Geodiferous Limerock or Swinestone." The outstanding characteristics noted by Eaton were the peculiar fetid odor and the abundant " geodes " containing " calc spar," " zinc blende," " fluor spar," and other minerals. The Niagara Falls area was mentioned as showing the geodiferous character particularly well.

The Lockport outcrop belt lay completely within the Third District as delimited in the first annual report of the New York State Geological Survey (1837). In this report (p. 178), Conrad placed the "Geodiferous Limerock " in the Onondaga Series, a transient assignment.

After the rearrangement of the Third and Fourth Districts at the beginning of the second year of the Survey, the examination of the Lockport between Niagara Falls and Wayne County was the responsibility of James Hall. The extension of the Lockport east of Wayne County was in the Third District, in charge of Lardner Vanuxem.

Hall (1838, pp. 302–303) observed that the "Geodiferous and Bituminous Limestone," on being traced eastward across the Fourth District, gradually lost its geodiferous character, and that the rock was bituminous, especially in its upper part. The Niagara Falls section was briefly described as a gray to brownish-gray, geodiferous rock. The uppermost part, above the falls, consisted of ". . . thin, almost slaty laminae with curved or contored structures. . . ." Mention was made of the hydraulic limestone in the transition zone between the underlying calcareous shale (Rochester) and the bituminous limestone.

Vanuxem (1838, pp. 278–279) included ". . . peculiar rock exhibiting a concretionary structure . . ." in the uppermost part of his Protean group.

Hall used the term "Lockport" for the first time, geologically, in the 1839 report on the Fourth District (p. 289). With the name, he gave an early example of what the description of a type section should include:

> "The limestone at Lockport excavated for the passage of the canal we propose to call Lockport limestone. At this place the rock possesses to an eminent degree the geodiferous character which has hitherto given it its name; but this is quite inapplicable to the same rock where seen in Wayne County. Yet it is believed that if thoroughly examined in all its varieties at Lockport, it will not be mistaken in its eastern prolongation where it becomes a dark, nearly black, compact limestone."

Hall (p. 327) listed the Rochester shale and the red shale (present Salina) as the underlying and overlying units respectively.

Vanuxem (1839, pp. 248–249) recognized the equivalency of the concretionary limestone and shale at the top of his Protean group and the Lockport limestone:

> ". . . we find that singular concretionary rock which forms the upper part of the Lockport and Niagara limestone, being the terminal mass in the Third District, and from which its name was in part derived."

The term "Niagara limestone" was thus used for the first time by Vanuxem. This usage proved popular, and after 1840 the name "Lockport" appeared only sporadically in the literature until the end of the century. Vanuxem (p. 242) further observed that the limestone thinned to about 3 feet in Oneida County.

In the Fourth Annual Report (1840, p. 452), Hall correlated the Lockport with the Wenlock limestone of England.

Vanuxem (1842, p. 90) described the Niagara group of the Third District as consisting of:

> ". . . limestone of a dark blue or black color, and of dark shale or slate. When the limestone is but small in quantity, it is in hemispherical concretions, whose parts are more or less concentric to each other, like the coats of an onion. The group is very thick in the fourth district, and forms the rocks of Niagara Falls; but it thins out to the east, leaving not a trace to be seen east of a line passing through the village of Mohawk in Herkimer County."

Hall, in his monumental final report on the Fourth District, placed the Niagara limestone and the underlying Niagara shale in the Niagara group (1843, p. 80). He (p. 87) believed that the limestone as exposed at Rochester persisted for a considerable distance westward. The following section was described (in superposed order):

> " 5. Thin-bedded dark-grey or brownish limestone. Few cavities. Highly bituminous. Sometimes contains nodules of hornstone."
>
> " 4. Thick-bedded dark or bluish-grey limestone with irregular cavities, and often siliceous accretions, or hornstone. Surface very ragged from weathering. Highly bituminous."
>
> " 3. A lighter colored subcrystalline mass very irregularly stratified, contorted and concretionary."
>
> " 2. A bluish grey subcrystalline mass, mostly thin-bedded, and separated by seams of dark shale."
>
> " 1. Grey or bluish grey siliceous limestone; hydraulic limestone or beds of passage from the shale below."

The type section along the Erie Canal south of Lockport was described by Hall (1843, p. 89) beginning above the hydraulic limestone:

> " 5. Thinly laminated blackish grey limestone with thin laminae of bituminous shaly matter; the whole exhibiting a tendency to a concretionary or contorted structure, and the surface of the layers marked by small knobs or elevations . . ."
>
> " 4. Greyish brown bituminous limestone, the lower part with irregular cavities containing spar; this passes upward into

more irregular beds of a dark color, containing few cavities but marked by the presence of blende."

" 3. A dark colored limestone, with cavities and veins of spar, often concretionary."

" 2. Irregularly thick-bedded limestone of a light grey color, with numerous cavities containing spar, etc."

" 1. Encrinital limestone, often beautifully variegated with red; entirely composed of encrinital columns and other fossils, which are always broken and worn."

The " Encrinital limestone," used for ornamental purposes, was known locally as " Lockport marble " (Hall, 1843, p. 448). Hall (p. 94) also noted the similarity between the concretionary structures in the Third and Fourth Districts.

The fossils of the Niagara limestone were illustrated and described in the second volume of the *Paleontology of New York* (Hall, 1852). At the same time, Hall prematurely correlated the Coralline limestone (present Cobleskill Formation) with the Niagara limestone (p. 321). Hall included in this monograph (pp. 340–350) a description of some pecular Silurian fossils from a limestone at Galt, Ontario.

In 1863, Logan (see Wilmarth, 1938, p. 886) proposed the name " Guelph " for strata overlying the Niagara limestone at Guelph, Ontario, and which he believed to be absent in New York. This was the same unit which Hall had examined and collected from in the Galt area. Logan described the formation as a fossiliferous, light-colored, porous, crystalline dolomite. Arey (1892) reported the presence of the Guelph fauna at Rochester, N.Y., in 4 feet of dolomite overlying the Niagara limestone.

Until 1899, confusion prevailed in regard to the various usages of the term " Niagara." It was employed by different authors as a group name, a formation name, and also as a time term. The situation was clarified by Clarke and Schuchert (1899, pp. 875–876). The name " Lockport limestone " was revived and was substituted for " Niagara limestone." " Niagaran " was used in its present sense to include the beds from the Clinton through the Guelph. The Guelph was considered a separate unit from the Lockport in New York State.

Grabau (1901, pp. 105–114) divided the Lockport limestone exposed at Niagara Falls into the Hydraulic cement beds, the Crinoidal limestone, and the Geodiferous limestones (in ascending order). Although the Guelph was apparently absent, Grabau suggested that it was possibly represented in the sequence of drift-covered Niagaran rocks beneath the Salina beds.

While traversing part of Orleans County in quest of the Guelph horizon which Arey had found at Rochester, Clarke and Ruedemann (1903) made a fortuitous discovery along Oak Orchard Creek, south of the village of Shelby. The creek had been artificially deepened in the 1870's in order to provide a more efficient drainage channel for Oak Orchard Swamp. The diggings had been piled on the banks, and in these the authors found fossils which were distinctly Guelph in character. The fossils were related to the exposed bedrock as follows (pp. 9–11; present author has arranged units in superposed order):

> " 7. Eight to 10 feet of gray dolomite, bearing white chert nodules . . . containing . . . *Trochoceras desplainense,* . . . *Tremanotus alpheus,* . . . This we shall term the upper Guelph bed and shall have occasion to observe that its fauna is more nearly parallel to that at Rochester than the lower or earlier appearance of the Guelph in this section."
>
> " 6. Twenty-four feet of similar dark gray dolomite with fossils extremely rare and of the same character as those below (Lockport limestone)."
>
> " 5. Eight feet of gray dolomite with few fossils and these characterizing the Lockport fauna; *Zaphrentis bilateralis, Enterolasma caliculus, Stropheodonta profunda, Orthothetes subplanus,* and a few others. This mass is capped by a thin bed of shaly limestone containing a profusion of small fossils . . ."
>
> "4. Three feet of dark gray dolomite. This is the lower Guelph bed. It contains a fairly profuse fauna, of which *Tremanotus alpheus* is the leading element, but *Monomerella noveboracum* the more exclusive species. . ."
>
> " 3. Two feet of porous dolomite, the cavities being vermicular or having the aspect of small tubes (Lockport limestone);"
>
> " 2. Sixty feet of hard, dark gray dolomites, full of small cavities bearing druses of dolomite and calcite, but with few or no fossils; . . . (Lockport limestone);"
>
> " 1. An exposure of normal Rochester shales . . ." (at the base of the falls at Shelby).

Unit 7, the southernmost exposure along Oak Orchard Creek, was believed to be only a few feet below the Salina. The names " lower Shelby dolomite " and " upper Shelby dolomite " were applied to the respective beds (units 4 and 7) containing the lower and upper Guelph faunas. Although Clarke and Ruedemann (1903, p. 14) did not find the Guelph beds at Niagara Falls, they claimed that the equivalent horizons were present. Their section was as follows (numbered by the present author):

7. " 25′ Brown dolomite exposed at Goat Island and Three Sisters Islands with summit near head of rapids. Full of cavities and with *Stromatopora, Halysites...*"
6. " 10′ . . . not exposed."
5. " 8′ Brown, thin bedded dolomites with rough surface and black partings."
4. " 12′6″ Thin bedded dolomite, fine grained and very hard. Continuous bed of chert nodules near top; probable horizon of upper Shelby fauna."
3. " 19 Compact drab dolomite; few cavities. Horizon of lower Shelby dolomite near top."
2. " 17′6″ Smooth, thin bedded dolomites with *Stromatopora*; at top *Enterolasma, Favosites.*"
1. " 28′ Compact light brown dolomite."
   " Rochester shale."

Unit 4, containing the probable horizon of the upper Shelby, or Guelph fauna, was just below the lip of the American Falls.

Hartnagel (1907, p. 24) reported about 130 feet of dolomite in the Rochester region and mapped the sequence as two distinct units, a lower " Lockport dolomite " and an upper " Lockport dolomite with interbedded Guelph faunas." He mentioned (p. 21) that a temporary excavation on Dufferin Islands at Niagara Falls revealed strata containing a mixed Lockport-Guelph fossil assemblage. It was noted that this was a higher horizon than the upper Shelby along Niagara Gorge and Oak Orchard Creek.

In the early part of the century, most geologists agreed that the Guelph should be excluded from Lockport dolomite in New York State (Grabau, 1909; Schuchert, 1910; Hartnagel, 1912).

In the Niagara Falls folio, Kindle and Taylor (1913) included a description of the Lockport dolomite as exposed in the Niagara Falls, Tonawanda, and Lockport quadrangles. The main rock type reported was a dark-gray to chocolate-colored dolomite. The basal part of the Lockport was the " hydraulic limestone " of earlier reports. The Gasport member was named and defined as follows (p. 7):

> " The basal beds are overlain by light-gray to white coarse-grained semicrystalline pure limestone, full of fragments of crinoid stems. This constitutes the Gasport limestone member, named from Gasport where it is well exposed . . . this bed has variously been called the Lower Niagara limestone,

> the Lockport Encrinal Marble, and the Crinoidal limestone. Its average thickness is 9 feet but in places it is more than 20 feet thick . . . The contact between the Gasport limestone and the beds beneath is sharp, without intergradation."

Although a few supposed Guelph species were found higher in the section, the Guelph was not considered to be a unit separable from the Lockport.

Hopkins (1914, p. 9) reverted to the term "Lockport limestone" in his mapping of the Syracuse quadrangle. Underlain by the Rochester shale and overlain by the Vernon, the Lockport was described as:

> ". . . a very dark colored, in places black, dolomitic limestone and associated shales. It contains numerous small geodic cavities lined with calcite and dolomite crystals."

The DeCew limestone was defined in Ontario by Williams (1914, p. 186) as follows:

> "In the Niagara peninsula, a fine-grained, dark grey, argillaceous limestone occurs at the base of the Lockport. It is especially well exposed at DeCew Falls, and for it the name DeCew is proposed."

Williams considered the DeCew to be transitional between the Rochester and the Lockport, but included it in the latter. The DeCew extends into western New York, where it had previously been referred to as the hydraulic limestone. In subsequent reports (1951a, 1915b), Williams excluded the Guelph from the Lockport in Ontario. He reported (1915b, p. 1) the discovery of an eurypterid zone in certain beds of the Lockport in southwestern Ontario. These beds represented a distinct unit, and to them the name Eramosa was applied:

> "The top of the Lockport member of the Niagara formation of Ontario consists of thin-bedded dark grey or chocolate brown bituminous dolomites which at some localities include bituminous shales. In some districts the cleavage along bedding planes is exceedingly even and slabs may be obtained that suggest roofing slates. Flagstones are quarried from such beds near Wiarton. At other localities the bedding is uneven, though thin. These characteristic beds are well exposed along the banks of the Eramosa river between Rockwood and Guelph, and for them the name 'Eramosa beds' is proposed."

Williams (1915b, p. 2) described the transitional nature of the Eramosa-Guelph contact, and also noted that *Monomerella,* a common Guelph brachiopod, was found associated with eurypterids in the Eramosa beds.

Chadwick (1917, p. 172) briefly described the "Lockport and Guelph dolomites" exposed temporarily in the Barge Canal cut at Rochester. Apparently, Chadwick thought that the Lockport and Guelph were separable. He claimed to have located the position of both Shelby horizons and recognized the presence of the Eramosa beds which Williams had named in Ontario.

In his study of the Clinton group (1918, p. 360), Chadwick thought he detected the existence of a considerable time break between the Rochester and DeCew. Consequently, he included the DeCew as the basal member of the Lockport. He believed (p. 354) that the Lockport in the Syracuse area was hardly separable from the overlying Pittsford shale and that it was probably this latter rock that makes its easternmost appearance on Steele Creek south of Ilion.

Williams (1919, pp. 57–63) separated the Guelph from the underlying Lockport in Ontario. The Lockport included the following members, from bottom to top: DeCew waterlime, Gasport dolomite, undivided Lockport, and Eramosa. The "undivided Lockport," characterized by abundant chert nodules in its lower beds, was not specifically named. Williams stated that the Guelph, comprising the beds above the base of the upper Shelby, was well defined in western New York. The lower Shelby dolomite was believed to be correlative with the *Monomerella* beds of the Eramosa.

Ulrich and Bassler (1923, pp. 259–260) felt that although Guelph fossils occurred in New York State, they were actually within the Lockport. They pointed out that the terms "lower Shelby" and "upper Shelby" of Clarke and Ruedemann (1903) were never intended as true lithologic units but rather as faunal zones or horizons possessing no lithologic distinctness.

Goldring (1931, p. 191) included the Guelph in the Lockport dolomite. The "Lower Shelby" and "Upper Shelby" dolomites were seemingly described as lithologic units.

Shaw (1937), in Ontario, regarded the Eramosa as a formation consisting of two members. The upper one, which was the original Eramosa named by Williams (1915b), was called the Speedwell member. The lower member, the Ancaster, corresponded to the "undivided Lockport" of Williams (1919). It was described as chert-bearing dolomite overlain by siliceous gray dolomite. In Shaw's opinion (p. 328), both the Eramosa-Guelph and the Guelph-Salina contacts were gradational.

Two years later, Cumings (1939, p. 597) restored the Eramosa to its original sense. The interval embraced by the Ancaster of Shaw was given a new name, the Suspension Bridge member, which was described as:

> ". . . about 50 feet thick on Niagara River, is brown, finely saccharoidal, medium-bedded dolomite with few fossils."

In this publication (p. 595), the DeCew, apparently for the first time, was placed in the Clinton group, disconformably overlain by the Gasport.

Gillette (1940) mentioned the prevalent tendency to use the term "Niagara" or "Lockport group" for that part of the Niagaran Series above the Clinton group. However, because only one formation, the Lockport dolomite, occurred in this interval, it seemed unnecessary to employ a group name. For his Clyde-Sodus Bay map area, Gillette used the name "Lockport dolomite," which included any Guelph which might have been present under the drift. Isolated outcrops showed the Lockport to be composed of dolomitic liemstone containing shaly partings. Some of the layers were bituminous.

The Silurian correlation chart (Swartz, et al., 1942) showed the DeCew limestone clearly separated from the overlying Lockport-Guelph group in western New York. It was pointed out, however (p. 535), that many geologists continued to place the DeCew in the basal part of the Lockport.

Gillette (1947) considered the Rochester as the uppermost formation of the Clinton. The DeCew was thus regarded as basal Lockport.

Two revisions in Lockport terminology were made in 1947 (Howell and Sanford, pp. 33–34). They found that the stratigraphic name "Shelby" was preoccupied and had been inappropriately used by Clarke and Ruedemann (1903). A new name was proposed for the interval including the lower and upper Shelby dolomites:

> "Since these beds are said by Clarke and Ruedemann to outcrop along Oak Orchard Creek, the new name, Oak Orchard Member, is here proposed for them." (1947, pp. 33–34)

The name "Suspension Bridge" was also found to be preoccupied and:

> ". . . must be replaced by a new name. The new name, Goat Island, is here proposed. The geological reference is to the island at the brink of Niagara Falls." (p. 34)

Howell and Sanford regarded the "DeCew Waterlime Member" as the basal member of the "Lockport Formation."

In the Oriskany quadrangle, Dale (1953) mapped as Lockport dark shales and dolomitic layers containing edgewise conglomerates and structures which he identified as stromatoporoid reefs.

Grossman (1953, pp. 70–71) dubiously applied the name " Lockport formation " to a 55-foot unit of shale and calcareous argillite in the Utica quadrangle.

By 1953, most Ontario geologists favored placing the DeCew in the Clinton group (Armstrong, 1953). The Lockport was given group status. The Ancaster dolomite was considered as a formation comprising the same interval as the Goat Island Member of the Niagara Falls area (Howell and Sanford, 1947).

Fisher (1954, p. 1,984) also felt that the Lockport-Guelph interval was as adapted to a group designation as was the Clinton, but he favored the name " Niagara group." He regarded the DeCew as the uppermost formation in the Clinton group, unconformably overlain by the Lockport.

Cannon (1955, pp. 140–149) divided the Lockport dolomite in Orleans County into lower and upper parts separated by a time break, part of which was correlated with the Eramosa member.

Fisher (1956, p. 624) criticized the use of the name " Lockport " for the predominantly shale equivalent in east-central New York because of the obvious lithologic difference between it and the dolomite to the west.

Bolton (1957, p. 49) retained the Goat Island as a member in the Niagara Peninsula although he thought it was better developed in Wentworth County, Ontario, west of the type section. The Ancaster cherty dolomite was not regarded as a true member but rather as a sequence in the lower part of the Goat Island member, typified by chert lenses and nodules. The DeCew was placed in the Clinton, disconformably below the Gasport. Bolton used the term " Albemarle group " to include the Lockport and Guelph formations in Ontario. The group embraces the same interval as the Niagara group (Fisher, 1954) and the Lockport group (Armstrong, 1953).

Fisher's *Correlation of the Silurian rocks in New York State* (1960) marked the first synthesis of Lockport terminology along the outcrop belt. The Lockport group in western New York was divided into six units. The lower three, in ascending order, were the Gasport, Goat Island, and Eramosa. The uppermost unit was called the Oak Orchard Dolomite, the term originated by Howell and Sanford (1947). Fisher, however, restricted the Oak Orchard to the upper Guelph horizon (or upper Shelby of Clarke and Ruedemann). The two units between the Eramosa and the Oak Orchard were named as follows:

> " Oakfield is proposed for the dolomitic limestones with a ' normal ' Lockport fauna lying beneath the Oak Orchard Dolo-

> mite (carrying a Guelph fauna) and above the eastwardly thinning wedge of dolomite carrying a Guelph fauna here named the Devil's Hole Dolomite. The latter is the Lower Shelby (name preoccupied) of Clarke (1903). The type section of the Oakfield is along Oak Orchard Creek at Shelby, Orleans County; that of the Devil's Hole Dolomite is at Devil's Hole State Park in the Niagara Gorge."

The Lockport was undivided in west-central New York. East of Syracuse, the Lockport equivalent was named the Ilion Shale and was described as follows:

> " The Ilion consists of about 60 feet of sparsely fossiliferous calcareous gray-black shale with interbedded dolomite layers containing stromatoporoids. Linguloids and eurypterids have been found in the shale. The type section is in Starch Factory Creek, 5 miles west-southwest of Ilion, Herkimer County (Utica quadrangle) where the unit is underlain by the Herkimer Sandstone and overlain by the Vernon Shale."

Table 1. Summary of Lockport nomenclature

Eaton (1824)	Secondary Class Geodiferous Limerock	Western New York
Conrad (1837)	Onondaga Limestone Series Geodiferous Limerock	Western and central New York
Hall (1838)	Geodiferous and Bituminous Limerock	Western and west-central New York
Vanuxem (1838)	Protean group Concretionary limestone	Oneida County
Hall (1839)	Lockport limestone*	Lockport, N.Y.
Vanuxem (1839)	Protean group Concretionary limestone and blue shale	East-central New York
Vanuxem (1839)	Lockport and Niagara Limestone	Western New York
Hall (1840)	Lockport limestone	Western and west-central New York
Vanuxem (1840)	Protean group Lockport limestone and calcareous shales	East-central New York

* See first paragraph of this chapter, p. 11.

Table 1. Summary of Lockport nomenclature (Continued)

Vanuxem (1842)	New York System			East-central New York
	Ontario Division			
	Niagara group			
	Dark blue limestone and dark shale			
Hall (1843)	New York System			Western and west-central New York
	Ontario Division			
	Niagara group			
	Hydraulic limestone	Encrinital limestone	Niagara limestone	
Hall (1852)	Niagara group			Western and west-central New York
	Niagara limestone			
Logan (1863)	Niagara limestone		Guelph formation*	Guelph, Ontario
Hall (1865)	Niagara limestone		Guelph formation	Ontario Peninsula
Arey (1892)	Niagara limestone		Guelph	Rochester
Dana (1895)	Niagara period			New York
	Niagara epoch			
	Niagara formation			

Table 1. Summary of Lockport nomenclature (Continued)

Clarke and Schuchert (1899)	Ontaric or Siluric Era						New York
	Niagaran period or group						
	Lockport limestone			Guelph dolomite			
Grabau (1901)	Lockport (Niagara) limestone						Niagara Falls
	Hydraulic cement beds	Crinoidal limestone	Geodiferous limestones	Guelph (?)			
Clarke and Ruedemann (1903)	Lockport dolomite			lower Shelby dolomite	Lockport dolomite	upper Shelby dolomite	Shelby, Orleans County
Hartnagel (1907)	Niagaran period or group						Rochester
	Niagaran age or stage						
	Lockport dolomite			Lockport dolomite with interbedded Guelph faunas			
Newland and Hartnagel (1908)	Niagaran period or group						Western New York
	Lockport dolomite			Guelph dolomite			
Grabau (1909)	Lower Silurian or Niagaran						Western New York
	Lockport			Guelph			
Schuchert (1910)	Niagaran series or epoch						Western New York
	Lockport			Guelph			
Hartnagel (1912)	Lockport dolomite			Guelph dolomite			Western New York

Table 1. Summary of Lockport nomenclature (Continued)

<table>
<tr><td rowspan="3">Kindle and Taylor (1913)</td><td colspan="4">Niagara group</td><td rowspan="3">Niagara Falls-Lockport area</td></tr>
<tr><td colspan="4">Lockport dolomite</td></tr>
<tr><td>“ Natural cement ”</td><td>Gasport* limestone</td><td colspan="2">Guelph dolomite (?)</td></tr>
<tr><td rowspan="2">Hopkins (1914)</td><td colspan="4">Niagara group</td><td rowspan="2">Syracuse, N.Y.</td></tr>
<tr><td colspan="4">Lockport limestone</td></tr>
<tr><td rowspan="3">Williams (1914)</td><td colspan="3">Niagara formation</td><td>Guelph formation</td><td rowspan="3">Ontario Peninsula</td></tr>
<tr><td colspan="3">Lockport member</td><td rowspan="2"></td></tr>
<tr><td>DeCew* limestone</td><td>Gasport limestone</td><td>Dolomite</td></tr>
<tr><td rowspan="2">Williams (1915a)</td><td colspan="4">Middle Silurian</td><td rowspan="2">Ontario Peninsula</td></tr>
<tr><td colspan="3">Lockport dolomite</td><td>Guelph dolomite</td></tr>
<tr><td rowspan="2">Williams (1915b)</td><td colspan="3">Niagara formation</td><td>Guelph formation</td><td rowspan="2">Ontario Peninsula</td></tr>
<tr><td colspan="2"></td><td>Eramosa* beds</td><td></td></tr>
<tr><td rowspan="2">Chadwick (1917)</td><td colspan="3">Lockport dolomite</td><td>Guelph dolomite</td><td rowspan="2">Rochester, N.Y.</td></tr>
<tr><td colspan="2"></td><td>Eramosa beds</td><td></td></tr>
<tr><td>Chadwick (1918)</td><td>DeCew member</td><td colspan="3"></td><td>Western and central New York</td></tr>
</table>

* See first paragraph of this chapter, p. 11.

Table 1. Summary of Lockport nomenclature (Continued)

<table>
<tr><td rowspan="2">Williams (1919)</td><td colspan="4">Lockport dolomite formation</td><td>Guelph formation</td><td rowspan="2">Ontario Peninsula</td></tr>
<tr><td>DeCew waterlime</td><td>Gasport dolomite</td><td>undiv. Lockport</td><td>Eramosa member</td><td></td></tr>
<tr><td rowspan="3">Ulrich and Bassler (1923)</td><td colspan="5">Niagaran series</td><td rowspan="3">Western New York</td></tr>
<tr><td colspan="5">Lockport dolomite</td></tr>
<tr><td colspan="4"></td><td>Guelph faunas</td></tr>
<tr><td>Monahan (1928)</td><td colspan="5">Lockport dolomite</td><td>Oneida County</td></tr>
<tr><td rowspan="3">Goldring (1931)</td><td colspan="5">Niagaran series</td><td rowspan="3">Western and west-central New York</td></tr>
<tr><td colspan="5">Lockport dolomite</td></tr>
<tr><td>Gasport limestone</td><td colspan="2"></td><td colspan="2">Guelph dolomite including Lower and Upper Shelby dolomites</td></tr>
<tr><td rowspan="4">Shaw (1937)</td><td colspan="5">Niagaran series</td><td rowspan="4">Niagara Peninsula, Ontario</td></tr>
<tr><td colspan="5">Lockport group</td></tr>
<tr><td>Gasport formation</td><td colspan="2">Eramosa formation</td><td colspan="2">Guelph formation</td></tr>
<tr><td></td><td>Ancaster member</td><td>Speedwell member</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Cumings (1939)</td><td colspan="5">Niagaran series</td><td rowspan="4">Western New York Ontario Peninsula</td></tr>
<tr><td colspan="5">Lockport group</td></tr>
<tr><td colspan="3">Lockport dolomite</td><td colspan="2">Guelph dolomite</td></tr>
<tr><td>Gasport dolomite member</td><td>Suspension Bridge member</td><td>Eramosa member</td><td colspan="2"></td></tr>
</table>

Table 1. Summary of Lockport nomenclature (Continued)

<table>
<tr><td rowspan="3">Gillette (1940)</td><td colspan="5">Niagaran series</td><td rowspan="3">Clyde-Sodus Bay area</td></tr>
<tr><td colspan="5">Lockport dolomite</td></tr>
<tr><td colspan="5">(including any Guelph present)</td></tr>
<tr><td rowspan="4">Swartz, et al. (1942)</td><td colspan="5">Niagaran series</td><td rowspan="4">Central and western New York</td></tr>
<tr><td colspan="5">Lockport-Guelph group</td></tr>
<tr><td colspan="3">Lockport dolomite</td><td colspan="2" rowspan="2">Guelph dolomite</td></tr>
<tr><td>Gasport limestone</td><td>Suspension Bridge dolomite</td><td>Eramosa beds</td></tr>
<tr><td rowspan="3">Gillette (1947)</td><td colspan="5">Niagaran series</td><td rowspan="3">Western and west-central New York</td></tr>
<tr><td colspan="5">Lockport dolomite</td></tr>
<tr><td>DeCew member</td><td>Gasport member</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Howell and Sanford (1947)</td><td colspan="5">Niagaran</td><td rowspan="3">Western New York</td></tr>
<tr><td colspan="5">Lockport formation</td></tr>
<tr><td>DeCew waterlime member</td><td>Gasport limestone member</td><td>Goat* Island member</td><td>Eramosa member</td><td>Oak Orchard member*</td></tr>
<tr><td rowspan="2">Dale (1953)</td><td colspan="5">Niagaran</td><td rowspan="2">Oriskany quadrangle</td></tr>
<tr><td colspan="5">Lockport</td></tr>
<tr><td rowspan="3">Grossman (1953)</td><td colspan="5">Niagaran series</td><td rowspan="3">Utica quadrangle</td></tr>
<tr><td colspan="5">Lockport group</td></tr>
<tr><td colspan="5">Lockport(?) formation</td></tr>
</table>

* See first paragraph of this chapter, p. 11.

Table 1. Summary of Lockport nomenclature (Continued)

<table>
<tr><td rowspan="2">Armstrong (1953)</td><td colspan="5">Lockport group</td><td rowspan="2">Niagara Peninsula, Ontario</td></tr>
<tr><td>Gasport dolomite</td><td>Ancaster dolomite</td><td>Eramosa dolomite</td><td colspan="2">Guelph dolomite</td></tr>
<tr><td rowspan="2">Fisher (1954)</td><td colspan="5">Niagara group</td><td rowspan="2">Western New York</td></tr>
<tr><td colspan="5">Lockport-Guelph interval</td></tr>
<tr><td rowspan="3">Cannon (1955)</td><td colspan="5">Lockport dolomite</td><td rowspan="3">Orleans County</td></tr>
<tr><td colspan="3">Lower part</td><td colspan="2">Upper part</td></tr>
<tr><td>Gasport member</td><td colspan="2">undifferentiated beds</td><td>Oak Orchard member</td><td>Guelph dolomite</td></tr>
<tr><td rowspan="4">Bolton (1957)</td><td colspan="5">Niagaran series</td><td rowspan="4">Niagara Peninsula</td></tr>
<tr><td colspan="5">Albemarle group*</td></tr>
<tr><td colspan="3">Lockport formation</td><td colspan="2">Guelph formation</td></tr>
<tr><td>Gasport member</td><td>Goat Island member</td><td>Eramosa member</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Moore (1958)</td><td colspan="5">Niagaran series</td><td rowspan="3">New York-Ontario</td></tr>
<tr><td colspan="5">Lockportian stage</td></tr>
<tr><td colspan="3">Lockport Dolomite</td><td colspan="2">Guelph Dolomite</td></tr>
<tr><td rowspan="3">Dunbar (1960)</td><td colspan="5">Niagaran series</td><td rowspan="3">Ontario-western New York</td></tr>
<tr><td colspan="5">Albemarle stage</td></tr>
<tr><td colspan="3">Lockport</td><td colspan="2">Guelph</td></tr>
</table>

Table 1. Summary of Lockport nomenclature (Concluded)

Fisher (1960)	Niagaran series						Outcrop belt New York see below
	Lockportian stage						
	Lockport group						
	Gasport limestone	Goat Island limestone, dolomite	Eramosa dolomite	Devil's Hole dolomite*	Oakfield limestone, dolomite*	Oak Orchard dolomite	—Western
	Lockport dolomite						—West-central
	*Ilion shale						—East-central

* See first paragraph of this chapter, p. 11

Structural Geology

Structures associated with the Lockport Formation are relatively simple. The dominent feature is the south-dipping homocline that affects the Paleozoic rocks of western and southern New York. Dips along the outcrop belt are low throughout, but they increase from west to east. Kindle and Taylor (1913, p. 14) computed a dip of 29 feet per mile at Niagara Falls. Gillette (1940, p. 15) stated that in the Clyde-Sodus Bay area:

> " The rocks dip to the south at the average rate of 43 feet a mile, or slightly more than the dip of the Silurian in the Rochester section."

The dip in the Utica quadrangle, as calculated from structural contour data of Kay (1953, map), is 80–90 feet per mile in a south-southwest direction.

Joints are common in the Lockport (see figure 2). An east-west, almost vertical, joint set was observed at many places but no statistical analysis was made. A study has been made of joints at the lip of the American Falls where major rockfalls have occurred through a combination of undercutting and slippage along widened joint planes (James R. Dunn, unpublished report).

Small undulations were seen at certain localities in western New York. Some, in the lower Lockport, are due to deposition on biohermal structures; others are a result of minor folding. Such flexures occur along the Barge Canal southwest of Lockport. A small anticline in the uppermost Rochester-DeCew sequence was revealed by excavations for the Niagara Power Project (loc. 3). At some outcrops, departures from the prevalent homoclinal dip are probably associated with local monoclinal flexures. However, undulations in some quarry floors are not tectonic but are due to rebound following the removal of overburden (Carl Helbock, 1960, personal communication).

A north-south structure extending from Linden to Clarendon (Albion quadrangle) causes a sharp offset in the Niagara Escarpment and the Onondaga Escarpment farther south. East of the offset, the

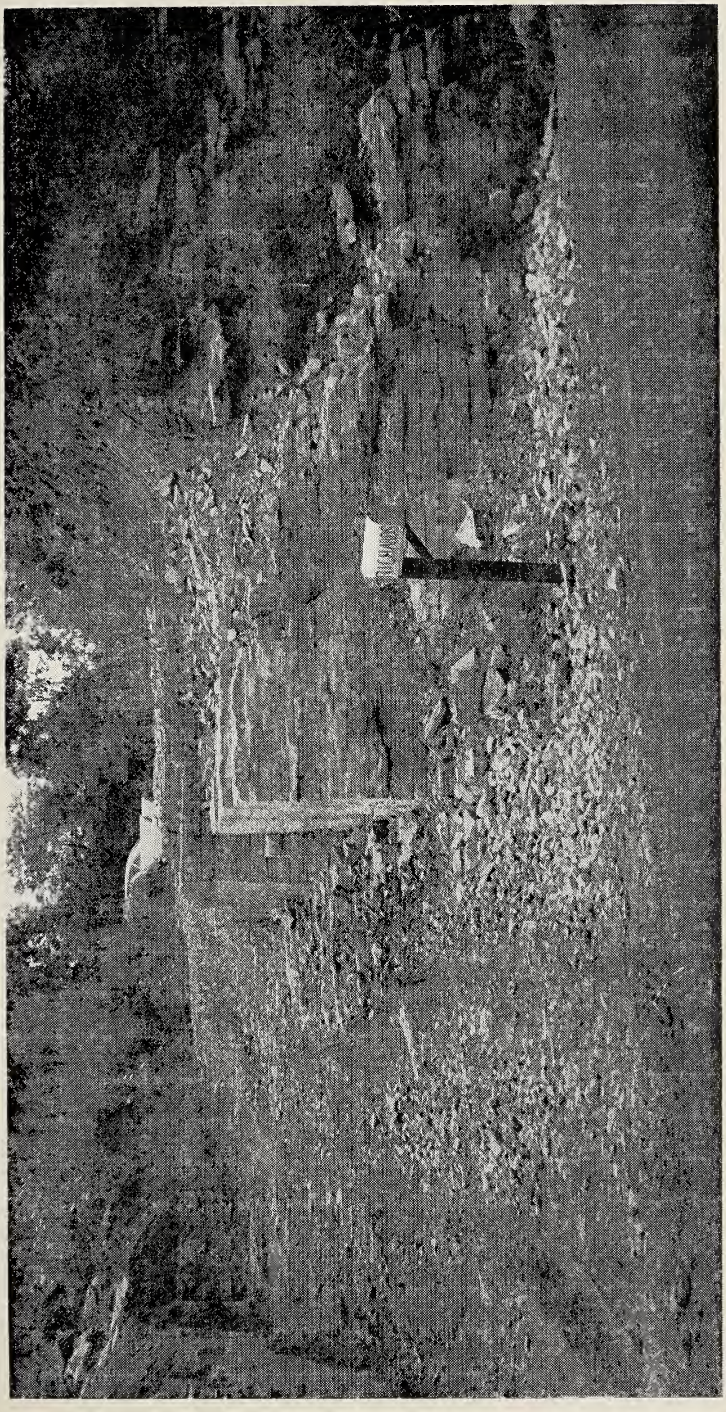

FIGURE 2. Vertical joints in Gasport Member on Niagara Escarpment south of Hickory Corners, Tonawanda quadrangle.

Niagara Escarpment lies 5 miles south of its position on the west side. Whether the structure is a monocline or a normal fault has been discussed repeatedly (Chadwick, 1920; Sutton, 1951; Cannon, 1955; and others). Cannon (1955, p. 121) considered that the offset is due to a fault and also suggested a cross fault west of the main structure. Although the offsets and steeper-than-normal dips near the structure (loc. 57) could result from folding, other evidence strongly suggests faulting. At the time of the Attica earthquake in 1929, some springs along the structure east of Batavia permanently increased their flow, whereas others decreased or even dried up (John G. Broughton, 1963, personal communication).

Drag of the beds along a small fault in the DeCew was seen beside a small creek flowing over the escarpment about 3 miles southwest of Albion (loc. 50).

A northwest-striking normal fault cuts the Gates-DeCew sequence along the Barge Canal at Rochester. The fault occurs midway between the Lyell Avenue and Lee Road bridges (loc. 82). The DeCew in the hanging wall on the north side is in contact with the Gates in the footwall. Stratigraphic relations indicate a displacement of about 15 feet. A few hundred feet to the south is a sharp-crested anticline, the axial plane of which strikes parallel to the fault.

Stratigraphy

REGIONAL

Across its outcrop belt, the Lockport is underlain by the Middle Silurian Clinton Group and overlain by the Upper Silurian Salina Group. Immediately underlying the Lockport, as far east as Oneida, is the Rochester Shale. East of Oneida, the Rochester is replaced by the Herkimer Sandstone. Above the Lockport in western New York is the Camillus Shale[2] (Fisher, 1960); east of Medina, the Vernon Shale is the overlying Salina unit.

STRATIGRAPHIC NOMENCLATURE

During the course of the investigation, it has become increasingly apparent that the Lockport Dolomite is most appropriately considered as a formation comprising several members. It is predominantly dolomitic and characterized generally by brownish-gray to dark-gray color, medium granularity, medium to thick bedding, stylolites, carbonaceous partings, vugs, and poorly preserved fossils. Differences within this general description permit the recognition of members (see figure 3). Two new members were proposed for part of the Lockport east of the Bergen quadrangle (Zenger, 1962). The proposed names, Penfield and Sconondoa, have been cleared for use through the Geologic Names Committee of the U.S. Geological Survey. Also, the Ilion Shale of Fisher (1960) is regarded as a member of the Lockport. These members represent facies of the Lockport. They are, however, persistent lithologic units that merit a formal stratigraphic designation. According to the Code of Stratigraphic Nomenclature (1961, p. 651):

---

[2] Leutze (1959) believed that the Syracuse Formation overlies the Lockport in western New York.

> " Although members normally are in vertical sequence, laterally equivalent parts of a formation that differ recognizably may also be considered members;"

In addition, " limestone lentil of the Lockport Formation at Brockport " is used for a local, distinct lithologic unit that occurs only in the Bergen quadrangle. This unit is not intended to be a formal one, and should have the same stratigraphic status as " beds."

Following a short section dealing with the thickness of the formation as a whole, each member in the various geographic areas will be treated under these headings:

Name and type section
Extent and thickness
Lithology
Microscopic petrography
Insoluble residues
X-ray diffraction
Contacts
Paleontology
Comments

Throughout the discussion, it will be helpful for the reader to have at hand Plate I (in pocket), the stratigraphic section and correlation diagram of the Lockport Formation in New York State. The stratigraphic and meridional distribution of the various sections and drill cores are shown, the numbered ones representing the selected sections described in detail in Appendix II.

THICKNESS

Determination of the thickness of the Lockport Formation is based on field measurements, diamond drill core studies, and published data, including gas well records. The most reliable thickness figures are obtained through either field work or diamond drill cores. There are, however, serious drawbacks to the use of these sources. Only in the Appalachian Plateau area (eastern area of this report) is the unit so well exposed that one can measure a complete continuous section. Along the rest of the outcrop belt, only an approximate thickness can be determined. There are very few diamond drill cores that include both the upper and lower contacts of the Lockport. The writer is

SILURIAN SYSTEM							
NIAGARAN SERIES						CAYUGAN SERIES	
Clinton Group	Lockport Formation					Salina Group	
Rochester Shale	DeCew Member	Gasport Member	Goat Is. Member	Eramosa Member	Oak Orchard Member	Camillus Shale	Niagara Falls
Gates Member	DeCew Member	Penfield Member			Oak Orchard Member	Vernon Shale	Rochester
Rochester Shale	Sconondoa Member					Vernon Shale	Syracuse
Herkimer Sandstone	Ilion Member					Vernon Shale	Utica

FIGURE 3. Classification of Lockport Formation in four representative quadrangles along outcrop belt.

aware of only two such cores: one drilled in Orleans County (Cannon, 1955, pp. 175–176) just south of the outcrop belt; and one drilled near Cuylerville, in Livingston County, about 25 miles south of Lockport exposures. Gas well records breed skepticism regarding their authenticity, for frequently such records have been provided by drillers possessing limited stratigraphic knowledge. In addition, the exact meaning of rock units as reported by gas companies is not always clear. Finally, records of neighboring wells commonly show thicknesses of the Lockport that contrast greatly with one another. In this particular project, gas well data were considered useful only in a general way.

Many of the published thickness figures for the Lockport Formation in the western part of the State are too low. Kindle and Taylor (1913, p. 7) reported 150 feet, including the DeCew, in the Niagara Falls area. Field measurements by the writer, however, revealed a section of about 180 feet and the uppermost part is not exposed. Judging from their geologic map (Kindle and Taylor, 1913), the top of the measured section (loc. 7) is at least 20 feet stratigraphically below the contact with the overlying Salina Group. Thus, the thickness of the formation at Niagara Falls must be about 200 feet. Cannon (1955, pp. 175–176), in a description of a diamond drill core from the southern margin of the Albion 7½ minute quadrangle, gave the depths of the upper and lower contacts. The computed thickness is 180.9, including the DeCew. This reliable figure, together with field relationships, contradicts the 110-foot thickness (including the DeCew) in the Medina quadrangle, as recorded by Clarke and Ruedemann (1903, p. 12). At Rochester, Hartnagel (1907, p. 24) estimated 130 feet of Lockport. Reed (1936, p. 10) arrived at a figure of 180 feet, including the thickness of the DeCew. By considering both the section along the Barge Canal (loc. 82) and that at Allen Creek (loc. 90), the present writer concludes that the thickness is approximately that reported by Reed. The diamond drill core from Cuylerville, 25 miles south of Rochester, shows slightly over 200 feet of Lockport. Gillette (1940, p. 99) did not give the thickness of the formation in the Clyde quadrangle because of the scarcity of outcrops there; however, he reported 156 feet from a gas well drilled at Geneva, about 20 miles to the south.

East of the Clyde quadrangle, the outcrop belt gradually narrows. This decrease in breadth is partially a reflection of an increase in dip, but primarily it is due to a thinning of the formation. A section compiled from a gas well located 2 miles south of Baldwinsville (Newland and Hartnagel, 1932, p. 142) lists a reasonable thickness of 140 feet. Hopkins (1914) made no mention of the thickness of the

" Lockport limestone " in the Syracuse quadrangle. An estimate of 120 feet, based on the width of the outcrop belt and dip of the formations at this longitude, is an approximation. East of the Chittenango quadrangle the rate of thinning increases. Slightly more than 75 feet are present in the eastern part of the Oneida quadrangle (loc. 154). At the College Hill section (loc. 158) in the Rome quadrangle, 70 feet of Ilion shales and dolomites were measured with a Brunton compass. Accurate thickness determinations were obtained at two places in the Utica quadrangle. At the type section of the Ilion Member (Fisher, 1960), along the eastern branch of Starch Factory Creek (loc. 165), this writer measured 41 feet between the exposed lower and upper contacts. On South Moyer Creek (loc. 166), about 4 miles to the southeast, the unit is 8 feet thinner. The Ilion is about 20 feet thick at its easternmost exposures along Steele Creek (Winfield quadrangle). In the next gorge to the east, near Spinnerville (loc. 173), Ilion lithology is absent and does not reappear farther east.

In summary, the thickness of the formation along the outcrop belt decreases slightly between Niagara Falls and Clyde, east of which the rate of thinning is more pronounced, particularly in the easternmost quadrangles. General trends in the subsurface (Kreidler, 1959) indicate that, with local exceptions, the thickness of the formation does not change appreciably in southern New York. Reed (1936, p. 10), however, listed thicknesses on the order of 300 feet in northwestern Pennsylvania.

STRATIGRAPHY OF THE WESTERN AREA

(Niagara Falls through Bergen quadrangles)

GENERAL

Except for the fine sections afforded by the Niagara Power Project operations (locs. 2–7) and the Niagara Stone quarry (loc. 9), most of the exposures are in the lower Lockport. Natural outcrops are numerous along the Niagara Escarpment; there are several active quarries near the edge of the escarpment or a short distance to the south. As a general rule, the greater the distance south of the escarpment, the fewer the outcrops owing to the increased thickness of the glacial deposits. Figure 4 shows the Lockport section in the Niagara Falls area (see also figure 5).

DECEW MEMBER

Name and type section. The DeCew " limestone " was named by Williams (1914, p. 186) for the exposure at DeCew Falls, Ontario.

Extent and thickness. The member extends across the western area. It is present in the Niagara Peninsula of Ontario as far west as Hamilton. Eastward, it extends into the west-central area of the outcrop belt. The DeCew is 8 feet thick at Niagara Falls and increases to 12 feet in the Tonawanda quadrangle. It is about 15 feet thick at Lockport and generally maintains this thickness to Rochester. At Medina and eastward, the DeCew caps the Niagara Escarpment.

Lithologic description. At Niagara Falls, the DeCew is medium-gray to medium dark-gray, fine-grained, thin- to thick-bedded and massive, argillaceous dolomite. Parts of the unit are very convolute, referred to by Grabau (1913, p. 758) as " enterolithic " structure (figure 6). There are many exposures along the escarpment east of Lewiston in the Tonawanda, Lockport, and Medina quadrangles. The lower part contains considerable intercalated shale and dolomitic shale. Although dark gray is prevalent, olive-gray to yellowish-brown layers are also common. The unit weathers to a distinct olive gray at most outcrops.

The " enterolithic " structure persists eastward, although it appears to have no consistent stratigraphic position. It was seen in the lower part of the unit on the Canadian side of Niagara Gorge, but is most striking in the upper part south of Lewiston (loc. 1). Shaly bedding, particularly in the lower half of the unit, as well as platy, straticulate layers, increases to the east. Laminations and cross laminations stand out on some weathered surfaces. Crinoidal beds are common in the uppermost part in the Lockport quadrangle, and to the east are found lower in the member. Zones of intraformational conglomerates occur throughout. Although the DeCew is predominantly dolomite, there are sporadic layers of dolomitic limestone and calcareous dolomite. Large-scale solution features, including caves, are characteristic of the

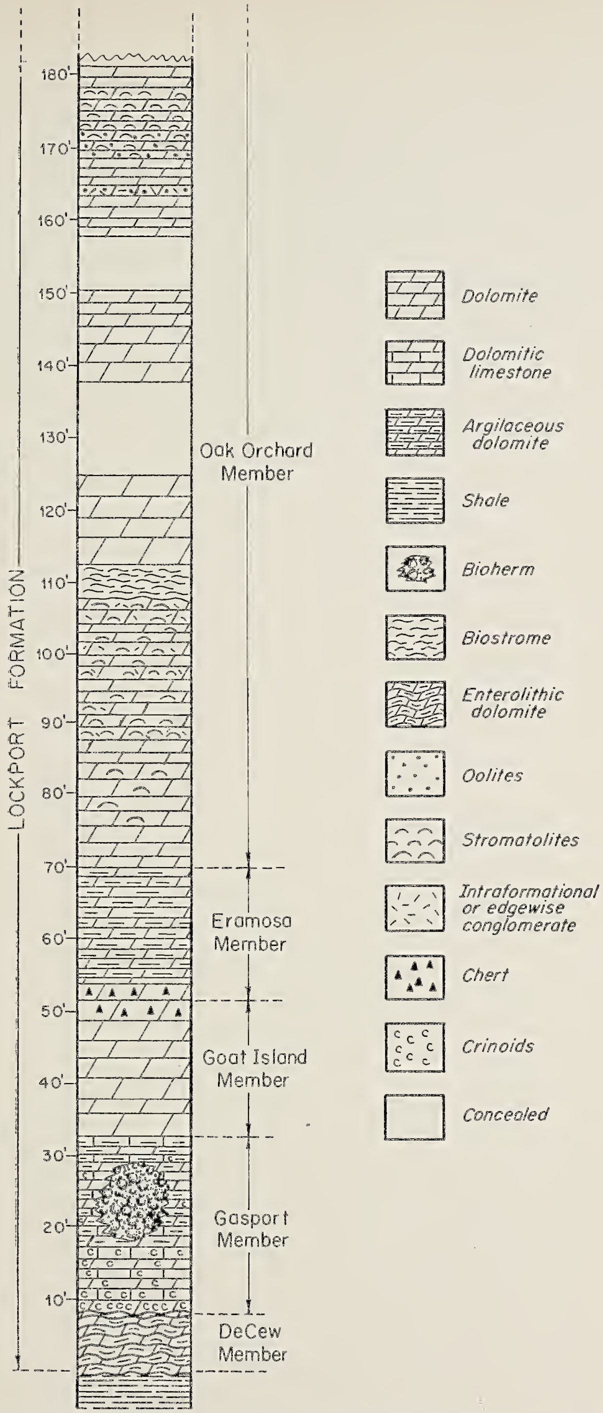

FIGURE 4. Columnar section of Lockport Formation in Niagara Falls area.

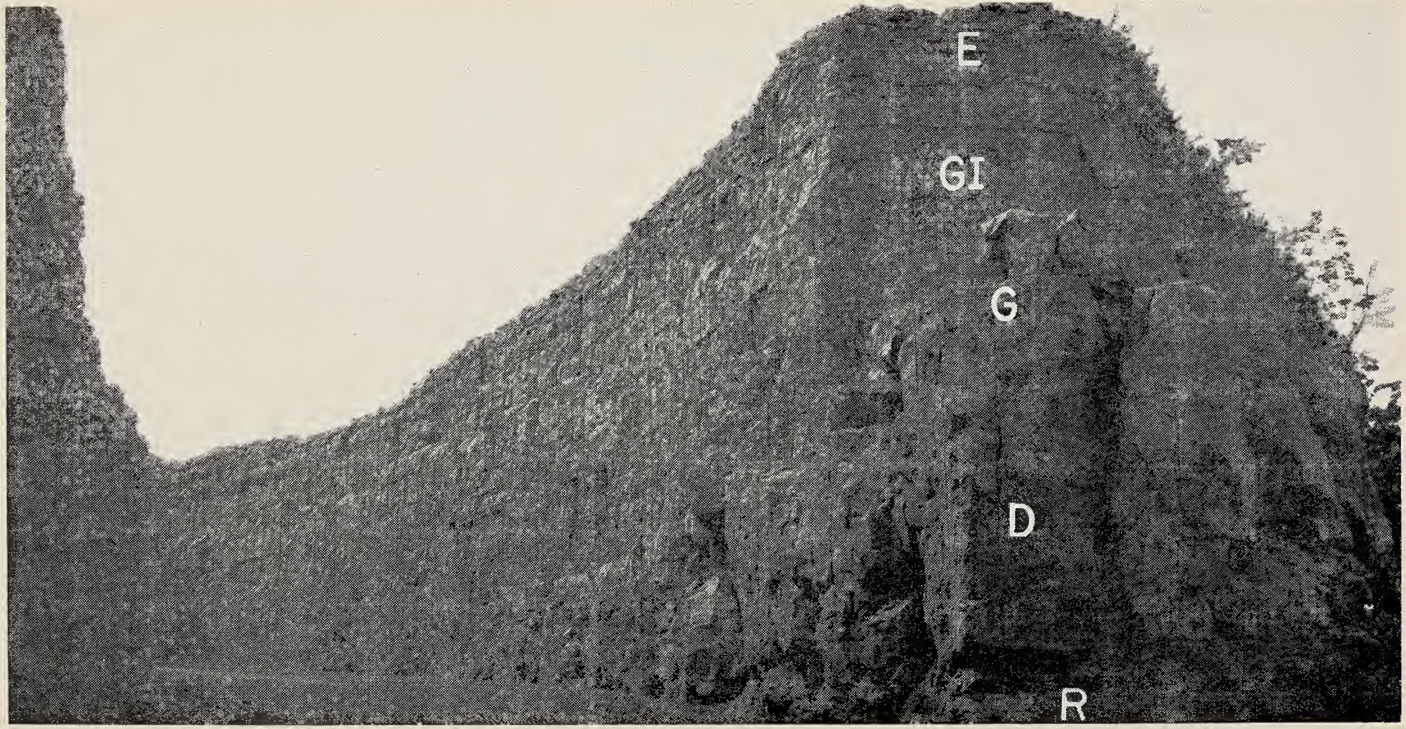

FIGURE 5. Lower Lockport along south haul road of Niagara Power Project (R=Rochester Shale, D=DeCew, G=Gasport, GI=Goat Island, E=Eramosa).

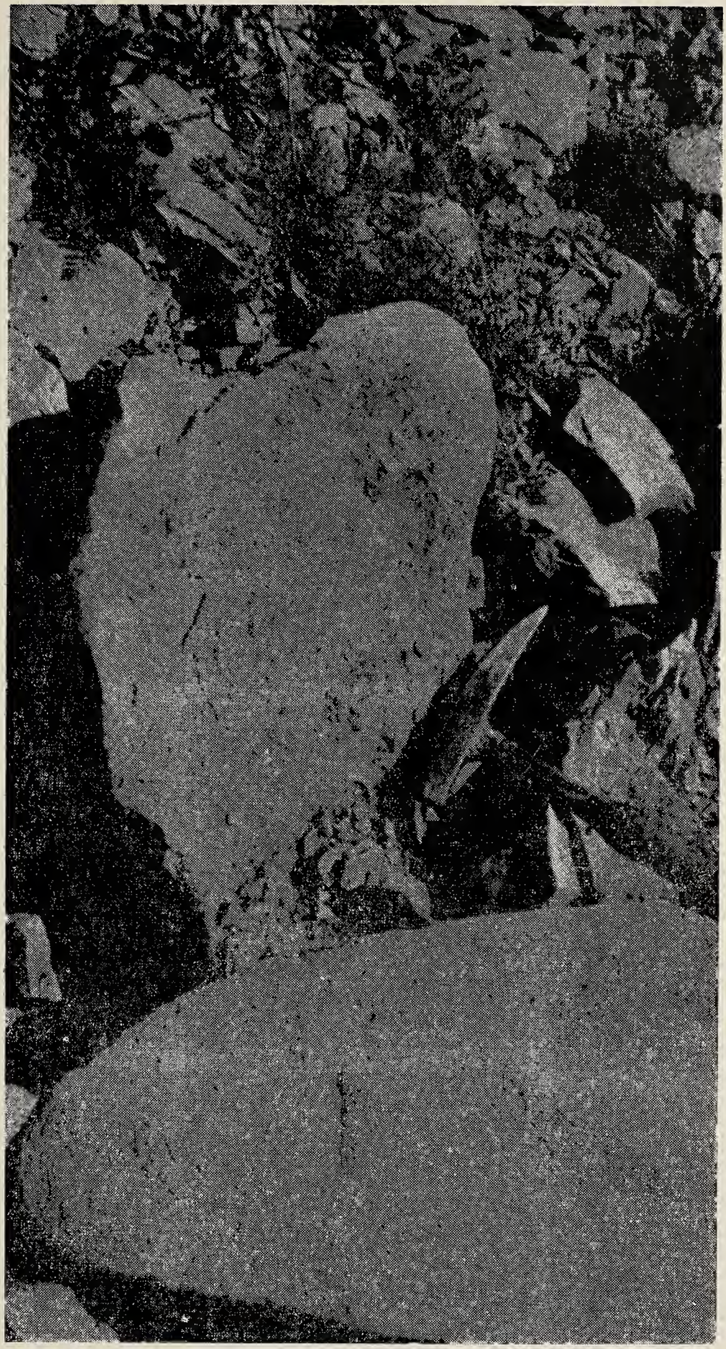

FIGURE 6. Enterolithic structure in lower DeCew at Concrete Materials quarry, Bergen quadrangle.

DeCew along the Niagara Gorge (William Brodie, 1961, personal communication). Devil's Hole, just west of Niagara University, is an example.

Microscopic petrography. A thin section of the massive bed along the south haul road (loc. 2) is considered as being fairly typical of the unit. The equigranular texture consists of interlocking, subhedral grains of dolomite. The average grain size is between .02 and .04 mm., although some grains are up to 0.1 mm. in size. Angular, corroded quartz grains constitute 5 to 10 percent of the section. Scattered grains of euhedral quartz may be authigenic. Dark argillaceous matter is disseminated and corrodes the dolomite and the quartz. Black, opaque, pyritic bodies probably represent carbonaceous material.

Insoluble residues. Nine samples between Niagara Falls and Brockport (Bergen quadrangle) averaged 26 percent insoluble. The change across the outcrop belt is significant. Insolubles are least in the west, averaging about 20 percent in the Niagara Falls and Tonawanda quadrangles. The impurities increase across the Lockport and Medina quadrangles and reach a maximum of 46.8 percent at Clarendon (Albion quadrangle). The figure drops to 30 percent in the Bergen quadrangle. Quartz is the most abundant component. It occurs as silt grains that generally are angular and clear. Argillaceous material bonds the quartz grains. Sphalerite and pyrite also are present.

X-ray diffraction. X-ray analyses and acid tests in the field indicate that dolomite is by far the predominant carbonate. One sample from the Frontier Dolomite Quarry (loc. 29), however, was analyzed as a dolomitic limestone.

Contacts. At Niagara Falls, the Rochester-DeCew contact is abrupt and undulating. It is definitely gradational in the rest of the western area. The lower DeCew consists of intercalated shale and argillaceous dolomite that grade upward from the Rochester Shale with no physical break between the units (see figure 7). The upper contact is more problematical. At Niagara Falls, the contact is sharp and is marked by a corrosion surface. The DeCew is green and fine grained just below the sharp contact with the crinoidal Gasport. In thin section, this green color is seen to be due to very finely disseminated pyrite. The exact contact is an irregular, dark, argillaceous and carbonaceous seam (see figure 8) that resembles a stylolite. This greenish zone can be traced eastward into the Lockport quadrangle. At some localities (e.g., locs. 29 and 32) the zone consists of elongate greenish pebbles. In spite of this corrosion surface, the writer does not believe there is an important break between the DeCew and Gasport Members. East of Niagara Falls, the uppermost strata of the

DeCew contain crinoid fragments; although these fossils are not as abundant as in the basal Gasport, their presence is significant. South of Cambria Center (loc. 19), there is an alternation of DeCew and Gasport lithologies. East of Lockport, the contact certainly is conformable.

Paleontology. (Appendix III contains notes on systematic paleontology of certain Lockport fossil groups). Fossils are rare and not well preserved in the DeCew. *Fardenia? decewensis, Atrypa reticularis,* and *Buthotrephis gracilis* are the most common species. A complete list of fossils collected during this investigation follows:

	Localities
Plantae	
Buthotrephis gracilis (Hall)	37
Brachiopoda	
Atrypa reticularis (Linnaeus)	14, 29, 57
Leptaena "rhomboidalis" (Wilckens)	28, 29
Stegerhynchus acinus (Hall)	69
S. neglectum (Hall)	29, 62, 63, 64
Fardenia? decewensis (Williams)	37
Strophonella patenta? (Hall)	28
S. striata (Hall)	28
Whitfieldella sp.	14
Gastropoda	
Platyceras sp.	69
Trilobita	
Dalmanites limulurus (Green)	64
Trimerus delphinocephalus (Green)	28, 64

Comments. Williams (1914, pp. 186–187) asserted that the DeCew represents reworked Rochester Shale, Although in places it appears that the DeCew is channeled in the Rochester, he saw no valid evidence of erosion. Williams considered the DeCew as transitional between the Rochester and Lockport, but he stated that it was more closely related to the latter.

Bolton (1957, p. 33) concurred with many of Williams' ideas but he placed the DeCew in the Clinton Group on debatable grounds. He regarded the Rochester-DeCew contact as transitional, but thought the Gasport contact to be unconformable because of the greenish zone

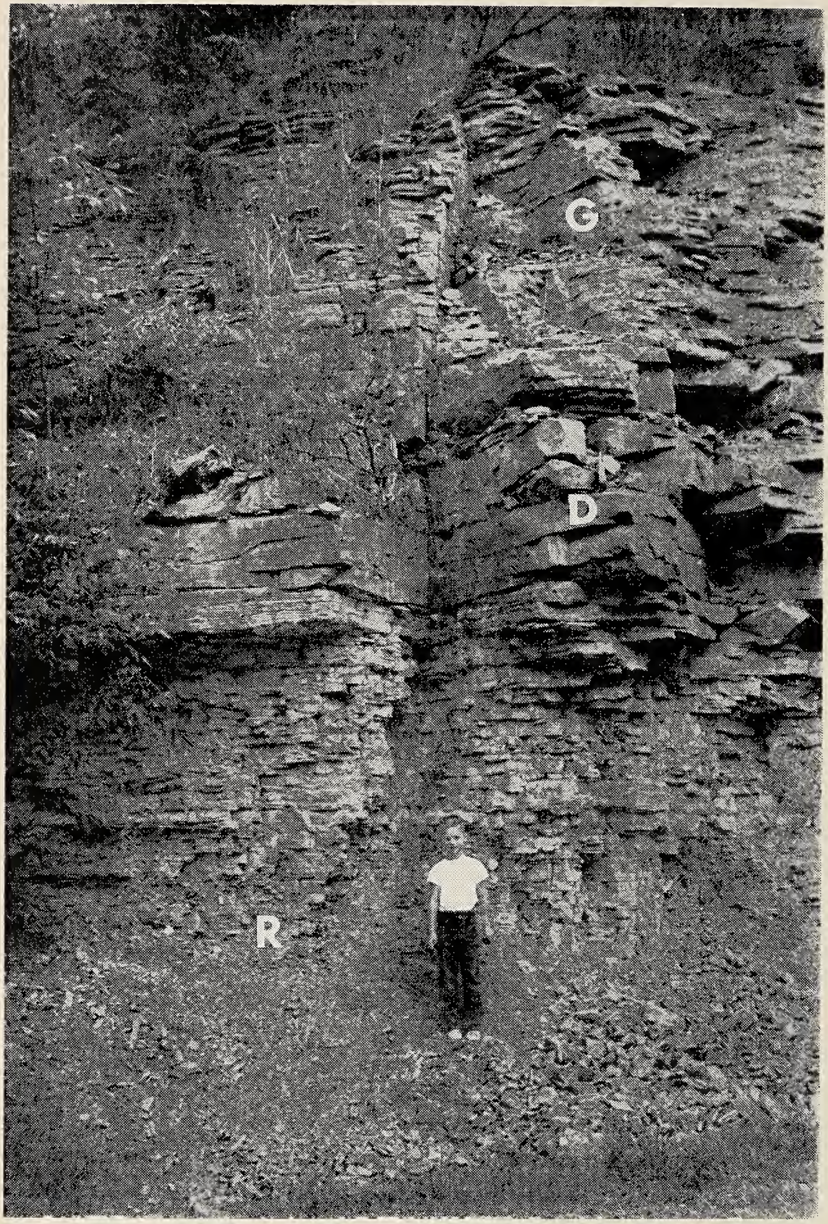

FIGURE 7. Uppermost Rochester (R), DeCew (D), and lower Gasport (G) on Niagara Escarpment south of Hickory Corners, Tonawanda quadrangle.

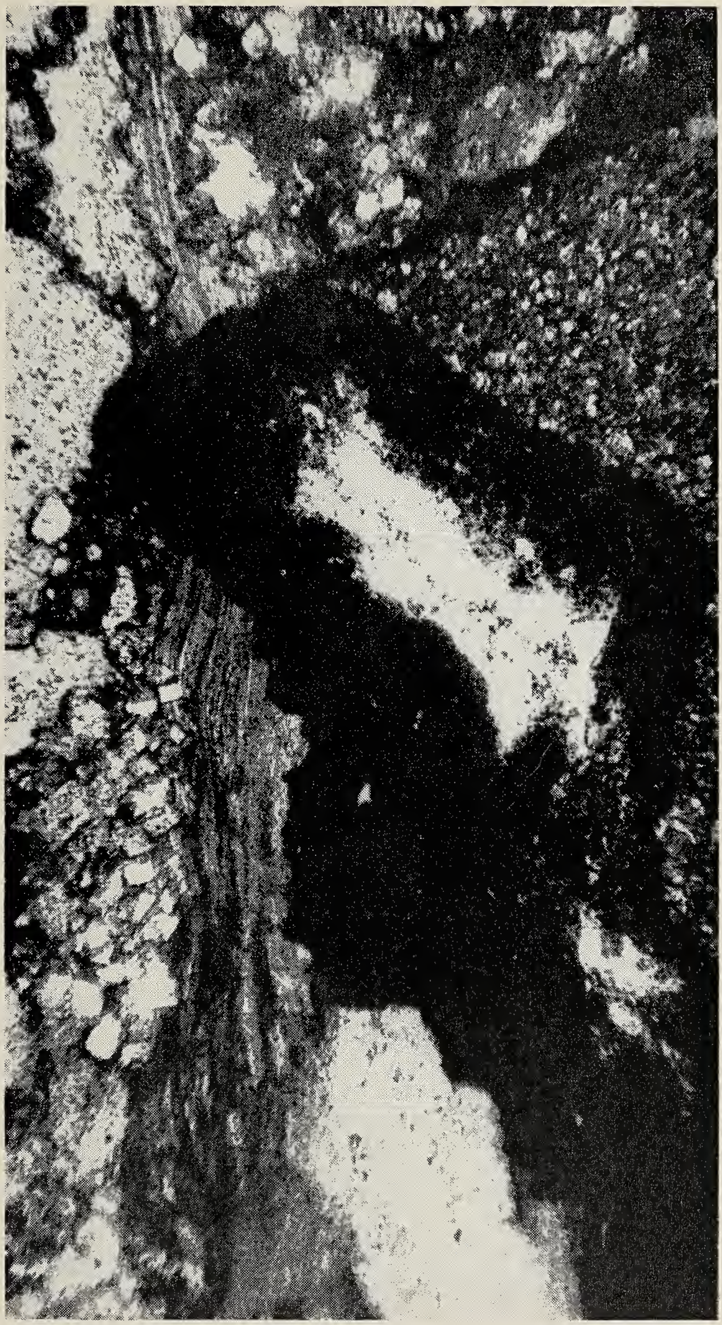

FIGURE 8. Photomicrograph. Corrosion surface marked by carbonaceous seam between fine-grained DeCew (below) and coarser Gasport (above) near Niagara Falls (plane polarized, X45).

at the top of the DeCew and pebbles of DeCew-like lithology in the basal Gasport. From these assumptions, he continued:

> " Many of the graptolites described by Bassler (1909) and Ruedemann (1947) were collected from argillaceous dolomites or dolomitic shales located some 6 feet below the chert beds in the Jolly-cut section at Hamilton [Ontario] : i.e., *Dictyonema granti, D. ramosum, D. subretiforme, Callograptus? multicaulis, C.? niagarensis, C. strictus, Dendrograptus? dawsoni, Thallograptus cervicornis, Diplospirograptus dubius,* and *Calyptograptus cyathiformis.* As these beds are considered representative of the DeCew dolomite, it follows that the graptolites are Clinton in age, and not Lockport as formerly proposed."

This writer is not in complete agreement with these statements. Bolton apparently believed that the DeCew is Clinton in age partly on the basis of the disconformable upper contact and the conformable lower one. In New York State the Rochester-DeCew contact is transitional, and a small, local hiatus may be represented by the DeCew-Gasport corrosion surface. Throughout much of the western area, however, the upper contact is conformable. Further, it is not certain that the graptolites found by Bassler and Ruedemann at Hamilton are strictly Clinton. Several of these species also were reported from the Gasport of New York (Ruedemann, 1925, pp. 7–8). Fisher (1960) excluded the DeCew from the Lockport because of the presence of *Trimerus delphinocephalus* and *Arctinurus boltoni,* which were unknown from the Lockport. During this investigation, however, *Trimerus delphinocephalus* has been found above the DeCew in the " limestone lentil " at Brockport.

That the DeCew is transitional between the Rochester and Lockport is unquestionable. The similarity (e.g., dolomite content, grain size, textures, bedding, topographic expression) to the Lockport, particularly in the west-central area, strongly suggests that the DeCew should be included in the Lockport as its basal member.

Grabau (1913, pp. 527, 756–759) attributed the " enterolithic " structure in the DeCew to changes in volume during dolomitization. Williams (1914, pp. 186–187), on the other hand, apparently felt that the " churned " structures resulted from a reworking of the underlying Rochester Shale. The present writer agrees that enterolithic (suggesting resemblance to intestinal convolutions) structures in salt and gypsum layers probably are due to crystallization or volume changes. However, the present opinion on dolomitization is that the substitution of dolomite for calcite is on a volume-for-volume basis, rather than molecule-for-molecule, as was formerly believed. Thus, it is very questionable whether the dolomitization of the DeCew could have resulted in such convolutions. The improbability of this is supported further by similar deformed bedding in the very slightly dolomitized " limestone lentil " near Brockport. Conceivably, the DeCew does represent reworked Rochester Shale, but it is doubtful that this reworking could have caused the disturbed bedding. Dunbar and Rodgers (1957, p. 192) pointed out that storm waves tend to move individual sand grains rather than masses of bottom sediment.

There is a striking similarity between these contortions and the flow rolls (" storm rollers ") in the Middle and Upper Devonian siltstones of New York. The latter are believed by some to have formed through submarine slump on a gentle slope. Dunbar and Rodgers (1957, p. 192) mentioned that in flow rolls ". . . some of the underlying mud has been squeezed up into the folds and faults in the deformed sandy layer." They also considered the possibility of overload causing an upward movement of mud around the curved masses of sand. It seems feasible that the contorted bedding in the DeCew is due to either submarine slumping or to a combination of this mechanism and upward movement in the sediment as a result of overload.

GASPORT MEMBER

Name and type section. Kindle and Taylor (1913, p. 7) named the Gasport Member for exposures near Gasport, N.Y. (Lockport quadrangle).

Extent and thickness. In New York State, the Gasport extends from Niagara Falls through the Albion quadrangle, capping the Niagara Escarpment in the western part of the belt. East of Brockport (Bergen quadrangle) the unit loses its identity although the crinoidal character is present, first in the lower Lockport and possibly farther east in the upper Rochester and Herkimer. Bolton (1957, p. 46) stated that a limestone equivalent to the type Gasport extends to north of Waterdown, Ontario. The thickness varies appreciably. On the United States side of the Niagara River, the thickness ranges from 15 to 23 feet. A brief examination of exposures on the Canadian side revealed a thickness in places up to 30 feet. In New York, the member reaches its maximum thickness of 30 feet in the Lockport and Gasport areas. Thinning in the Medina and

Albion quadrangles results in a thickness of only 13 feet at Clarendon (loc. 57), the easternmost exposure of typical Gasport.

Lithologic description. Although it is composed of a complex of facies, the Gasport is predominantly olive-gray to brownish-gray, coarse-grained, medium- to thick-bedded, fossil-fragmental, crinoidal[3] limestone or dolomite. Across the outcrop belt, this lithology invariably is present, especially in the lower part of the unit. This main lithology is herein spoken of informally as the "crinoidal facies."[3] The abundant crinoid and brachiopod fragments are in the coarse-grained range and the rock could be classed petrographically as a calcirudite or dolorudite. The matrix is much finer grained and slightly argillaceous. Here and there the beds are very porous. The bedding varies from even to irregular and undulating. Biostromal layers contain corals and stromatoporoids, which commonly are not in growth position. A stromatoporoid biostrome is well exposed at the top of the Royalton Stone quarry (loc. 37) at Gasport.

Small bioherms represent another but more local facies. These structures are discussed in greater detail later in the report. Bioherms are exposed along the Niagara River and at localities 14, 24, 28, 29, 37, and 57 in the Tonawanda through Albion quadrangles. Their petrography is very similar, consisting of light-gray, fine- to very fine-grained, structureless, argillaceous, compact limestone or dolomite. Crinoid fragments are much less abundant than in the crinoidal facies. Corals and stromatoporoids are abundant and rather well preserved in the limestone bioherms. On first examination, the dolomite bioherms appear unfossiliferous. A closer inspection reveals that stromatoporoids are present, but their preservation is extremely poor.

The third Gasport facies, as considered by the writer, is the "dark, bedded facies." Dark-gray, thin- to medium-bedded, fine- to medium-grained, argillaceous dolomite was observed above the crinoidal facies in sections exposed by the power project operations. The inclusion of sporadic crinoid columnals suggests a close association with the Gasport. Farther east, sections in the Frontier, Royalton, and Clarendon quarries (locs. 29, 37, 57, respectively) clarify the relation of this lithology to the other facies of the Gasport. These dark beds overlying the crinoidal facies grade laterally into bioherms. Between the margins of some bioherms and the "dark, bedded facies" are dark dolomitic layers much like the latter but containing a profusion of coral and stromatoporoid fragments. Undoubtedly, these beds represent bioherm detritus. Ruedemann (1925, pp. 7–8) referred to

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[3] As used here, the term crinoidal includes undifferentiated pelmatozoan fragments.

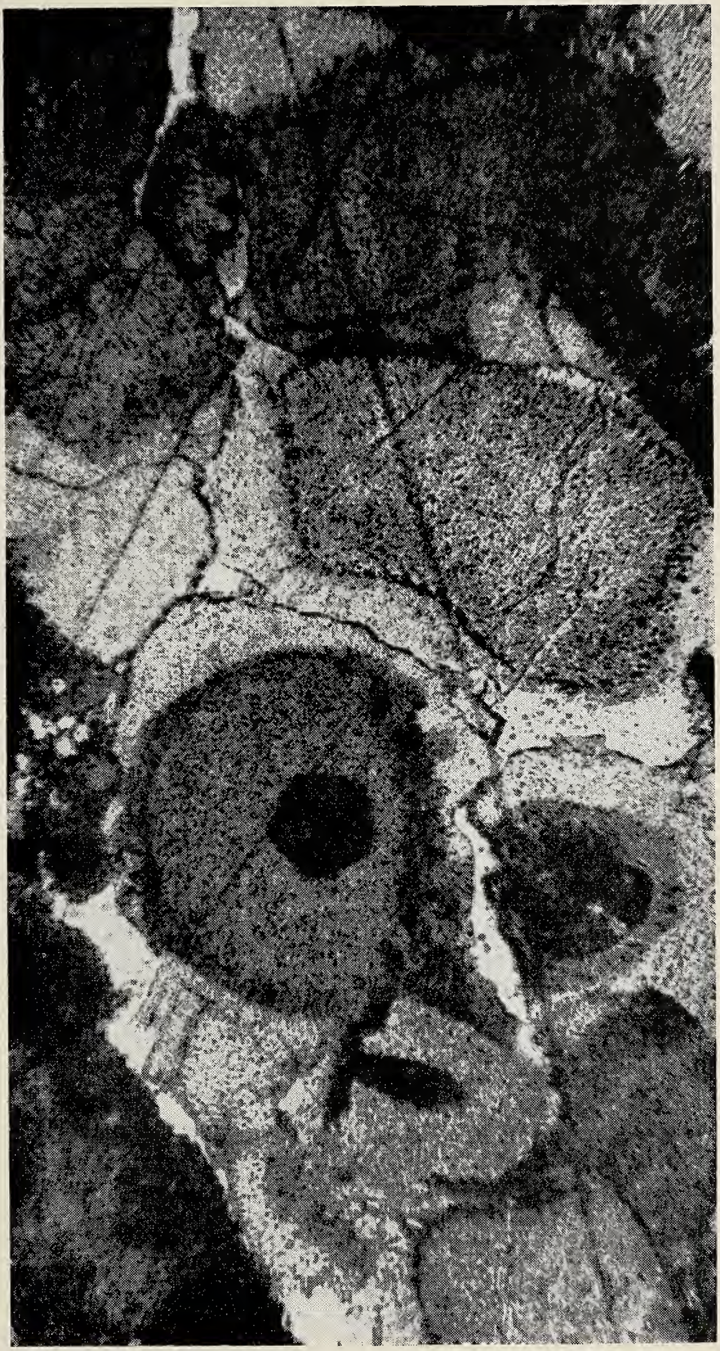

FIGURE 9. Photomicrograph of lower crinoidal limestone of Gasport. Note calcite in optical continuity with crinoid columnal (plane polarized, X40).

such dark beds south of Gasport as "the Gasport 'Channel' beds of the Lockport limestone"; apparently he believed that they are developed only at that locality.

Laminations and cross laminations are visable on some weathered surfaces, particularly in the crinoidal facies. Vugs are numerous in the biostromal and bioherm-detrital beds. These voids mark the positions of former fossils. Minerals, such as dolomite, calcite, galena, sphalerite, and gypsum, occur in the member, primarily in the vugs. Some asphalt-like hydrocarbons were observed along the Niagara Gorge.

Microscopic petrography. A thin section of the lower crinoidal, dolomitic limestone at Lewiston (loc. 1) consists of rounded fossil fragments, predominantly pelmatozoans, embedded in finer-grained matrix and sparry calcite cement (see figure 9). Most of the fragments are coarse-grained, although some are medium-grained. The matrix, some of which obviously consists of comminuted fossil fragments, ranges in grain size from .02 to 0.3 mm. Clear calcite cement makes up less than 10 percent of the section. Numerous euhedral dolomite rhombs show replacement relations with respect to fossil fragments. Most of the crinoid columnals are bordered by clear calcite that has grown in optical continuity with the fossil (see figure 9). Quartz grains, comprising a very small percentage of the section, commonly are less than .05 mm. in greatest dimension. Most of these quartz grains are strained and corroded. Euhedral quartz with calcite inclusions probably are authigenic. Argillaceous matter is disseminated throughout in minor amounts.

A thin section of the porous, dolomitized Gasport from the Royalton quarry (loc. 37) shows the texture to be interlocking and more crystalline than the crinoidal limestone. The dolomite grains range in size from .04 to 0.1 mm. and average just into the medium-grained division. A few detrital quartz grains and pyritized pellets are present. The porosity is high, averaging about 30 percent of the section. Polysynthetically twinned gypsum occurs in some of the larger pores.

The texture of a sample of the dolomitized bioherm at the Royalton quarry consists of interlocking anhedral dolomite grains averaging in size between .02 and .05 mm. The matrix is a very fine-grained dolomite. The rock could be classed as a biolithite (Folk, 1959a). Most of the former pores and fractures are filled with quartz and secondary dolomite.

The grain size of a bioherm-detritus bed ranges from .02 to over 2.0 mm., although most of the grains are between .05 and 1.0 mm. in size. Finer-grained zones of argillaceous material corrode the dolomite. Some fossil fragments are silicified. The porosity is high, averaging between 30 and 35 percent.

Insoluble residues. Insolubles in the crinoidal facies are very low, averaging just over 2 percent. The bioherms and the dark, bedded facies are noticeably more impure, averaging about 13 percent insoluble. Clear, angular quartz grains and clay constitute the chief portion of the residues. Pyrite, spalerite, and gypsum are present.

X-ray diffraction. The pattern of a sample from the lower, crinoidal " limestone " south of Lewiston (loc. 1) revealed a surprisingly high amount of dolomite, about 35 percent, as determined from calcite-dolomite ratios.

Contacts. The lower contact with the DeCew Member has been discussed. One additional point is worthy of mention. No basal conglomerate of DeCew pebbles, such as Bolton described (1957, p. 46), was observed at the base of the Gasport in New York. The writer did, however, collect samples of this conglomerate from the Gasport on the Canadian side of the Niagara Gorge. X-ray analyses of the dark pebbles show predominantly dolomite with some quartz. This composition, together with the fine texture of the pebbles, indicates the DeCew lithology. The conglomerate strongly suggests a local break in sedimentation between the DeCew and Gasport. The upper contact with the Goat Island Member is rarely exposed. It may be gradational or abrupt, but it consistently appears to be conformable. The contact is drawn arbitrarily at some localities. At the Frontier Dolomite quarry, for example (loc. 29), units 5–8 are placed in the Goat Island on the basis of a lithology different from that of the Gasport although sporadic crinoid fragments are present. Because some of the typical Gasport bioherms extend upward just into the Goat Island interval, there is probably at least a slight facies relationship between the uppermost Gasport and the lowermost Goat Island.

Paleontology. The Gasport is the most fossiliferous unit in the Lockport of New York. Many groups are well represented. Exposures at Lewiston, Hickory Corners, and " The Gulf " (locs. 1, 23, 28) provide good collecting from the lower crinoidal Gasport. Brachiopods dominate these assemblages, the most common species being *Atrypa reticularis, Whitfieldella nitida, Leptaena "rhomboidalis," Eospirifer radiatus, Hedeina crispa, Stegerhynchus neglectum, Rhynchotreta americana,* and *Parmorthis elegantula.* Corals are second only to the brachiopods in both number of species and number of individuals. They are most numerous in the bioherms and biostromes, but they occur sporadically in the other facies.

Cystiphyllum niagarense is the most abundant coral in the bioherm at Pekin (loc. 4), and *Palaeophyllum multicaule, Favosites pyriforme,* and *Heliolites pyiformis* are common. In a similar bioherm west of Lockport (loc. 24), *Cystiphyllum niagarense, Palaeophyllum multicaule,* and species of *Favosites* are abundant; they are associated with less numerous specimens of *Cladopora seriata, Diplophyllum caespitosum,* and *Halysites* sp. Most of these corals also are found in the biostromes. *Enterolasma caliculum* is rather common throughout the various facies. The fragmentary nature of the bryozoan remains makes their specific identification a formidable task. *Hallopora elegantula, Chasmatopora asperatostriata, Clathropora frondosa, Chilotrypa ostiolata?,* and *Fenestrellina elegans* are among those collected. Like the corals, the stromatoporoids are most abundant in the bioherms and the biostromes. Generally, internal structures are not well preserved and a specific identification usually is not feasible. Pelmatozoan fragments are characteristic of the member. Unfortunately, most of the calices have become disarticulated. *Caryocrinites ornatus* and *Eucalyptocrinites* sp. are the most common forms. Hall (1852) described several crinoid genera from the lower Lockport, or Gasport. Many of the crinoid fragments are reddish. A freshly broken fragment shows the color internally and thus refutes the possibility of it being simply a surface stain. Presumably, the reddish coloration is due to trace amounts of either iron or manganese. Mollusks are uncommon and only *Dawsonoceras, Naticonema,* and *Platyceras* have been found. One specimen each of *Dictyonema retiforme* and *D. subretiforme* was found, the latter in the dark, bedded facies. Trilobites apparently are very rare, a specimen of *Dalmanites* being the sole representative. Table 2 gives the list and distribution of Gasport fossils found during this investigation.

Comments. Pelmatozoan fragments, an abundant faunal assemblage, and small bioherms are the outstanding characteristics of the Gasport. Kindle and Taylor (1913, p. 7) stated that the Gasport becomes more magnesian west of Lockport. This writer, however, is convinced that there is not a consistent trend of dolomitization within the Gasport. For example, the unit at the Royalton quarry (loc. 37) is exclusively dolomitic, whereas at Lewiston, 20 miles to the west, it is predominantly limestone. Down dip from Lewiston, at the south haul road (loc. 2), the Gasport is dolomite, but a mile or so to the east (loc. 3) it consists of interbedded limestone and dolomite.

Table 2. Distribution of Gasport fossils

Fossils	Localities										
	1	3	14	23	24	28	29	31	37	43	57
Stromatoporoidea											
Clathrodictyon vesiculosum Nicholson and Marie			X								
Parallelopora cf. *ostiolata* Bargatsky					X						
Stromatopora concentrica? Goldfuss*											
Syringostroma? sp.				X							
Stromatoporoidea indet.		X				X	X		X		X
Anthozoa											
Amplexus? sp.						X					
Cladopora cervicornis Hall				X	X				X		
C. fibrosa? Hall				X		X			X		
C. multipora Hall				X		X					
C. reticulata Hall						X					
C. seriata Hall					X				X		
Cystiphyllum niagarense (Hall)			X	X	X	X					
Diplophyllum caespitosum Hall					X	X		X			
Enterolasma caliculum (Hall)		X		X		X					
Favosites niagarensis (Hall)		X				X			X		
F. pyriforme (Hall)			X								
F. sp. A					X	X		X	X		X
F. sp. B					X	X					
F. sp.				X							
Halysites cf. *nitida* Lambe											X

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* In float just west of loc. 14.

Table 2. Distribution of Gasport fossils (Continued)

Fossils	Localities										
	1	3	14	23	24	28	29	31	37	43	57
H. sp.					X	X	X		X		
Heliolites elegans Hall					X						
H. pyriformis Guettard			X			X					
H. spinipora? Hall						X					
Palaeophyllum multicaule (Hall)		X	X							X	
Striatopora flexuosa (Hall)					X	X		X			
Zaphrentis sp.				X	X						
Bryozoa											
Ceramopora sp.	X										
Chasmatopora asperatostriata (Hall)	X		X	X		X	X				
Chilotrypa ostiolata? (Hall)	X										
Clathropora alcicornis Hall						X					
C. frondosa Hall	X					X					
Diamespora? sp.			X	X	X	X					
Fenestrellina elegans (Hall)	X		X								
Hallopora elegantula (Hall)	X			X	X	X					
Lichenalia concentrica Hall	X										
Semicosinium tenuiceps Hall					X						
Brachiopoda											
Atrypa nodostriata? (Hall)	X			X		X					
A. reticularis (Linnaeus)	X			X		X				X	
Cyrtina pyramidalis (Hall)	X			X							

Table 2. Distribution of Gasport fossils (Continued)

Fossils	Localities										
	1	3	14	23	24	28	29	31	37	43	57
Eospirifer niagarensis (Conrad)				X	X	X			X		
E. radiatus (Sowerby)	X			X		X					
Hedeina crispa (Linnaeus)	X			X		X					
Howellella? sp. A					X	X					
Leptaena "rhomboidalis" (Wilckens)	X			X		X	X		X		
Parmorthis elegantula (Dalman)	X			X	X	X					
Plectodonto transversalis (Sowerby)						X					
Plectodonta transversalis (Sowerby)	X										
Rhynchotreta americana Hall	X			X	X	X		X			
Stegerhynchus neglectum (Hall)	X			X		X		X			
Strophonella? decewensis Williams	X										
S. patenta (Hall)	X										
S. striata (Hall)	X				X						
S. sp.				X		X					
Trematospira camura (Hall)					X	X					
Uncinulus obtusiplicata (Hall)	X				X						
Whitfieldella cylindrica (Hall)				X		X					
W. nitida (Hall)	X			X		X					
W. oblata (Hall)	X			X		X					
Pelecypoda											
Cornellites emaceratus (Conrad)				X							

Table 2. Distribution of Gasport fossils (Concluded)

Fossils	Localities										
	1	3	14	23	24	28	29	31	37	43	57
Gastropoda											
Naticonema hemisphericum (Hall)							X		X		
Platyceras niagarense (Hall)	X										
Cephalopoda											
Dawsonoceras americanum (Foord)						X	X				
Pelmatozoa											
Caryocrinites ornatus Say				X	X	X		X			
Eucalyptocrinites sp.						X		X			
Pariechocrinus? sp.									X		
Graptozoa											
Dictyonema retiforme (Hall)						X					
D. subretiforme (Spencer)							X				
Trilobita											
Dalmanites limulurus (Green)							X				

LIMESTONE " LENTIL " OF THE LOCKPORT FORMATION AT BROCKPORT

Name and type section. Limestone " lentil " of the Lockport Formation at Brockport is proposed for rocks exposed southeast of the village of Brockport, in the Bergen quadrangle. The type section is in the Concrete Materials quarry about 3 miles southeast of Brockport (loc. 63). Because of its limited extent, the unit is not considered a formal one. It is hoped that the above name, despite its lengthiness, expresses the informal nature of the unit.

Extent and thicknesss. The " lentil " is very local, being exposed only in the Bergen quadrangle. Although the general shape appears to be that of a small lens, there are insufficient exposures to delineate it accurately. Furthermore, there are no data available regarding the extent of the unit to the south. The thickness at the type section is 21 feet and, although the upper contact is not exposed, field relationships indicate that the unit is not much thicker.

Lithologic description. These beds generally are medium dark-gray, fine-grained, medium-bedded, fossiliferous limestone. There are intercalated beds of coarser-grained, crinoidal limestone. Laminated strata and thin zones of intraformational conglomerates also are characteristic. The irregular bedding in the lower part resembles that in the underlying DeCew, whereas the bedding in the upper part is thin and even.

Microscopic petrography. Fossil fragments and pellets are embedded in a fine-grained matrix of anhedral calcite. The rounded pellets average in size between .06 and .08 mm. and consist of microcrystalline calcite. Some of the matrix is argillaceous. Small euhedral rhombs showing replacement relations probably are dolomite. The rock is only slightly porous, most of the voids having been filled with secondary calcite. Shells lie parallel to the stratification. Angular, detrital quartz grains, mostly between .06 and .12 mm. in greatest dimension, constitute more than 20 percent of the section. Many of the fossils are pyritized.

Insoluble residues. Only two samples of the unit were acidized; these were 22.3 percent and 32.4 percent insoluble. Most of the insoluble is quartz silt and sand.

X-ray diffraction. Dolomite is very minor, judging from the smallness of a peak at $2\theta = 31°$. As was suggested in the thin-section study, the composition is calcite with considerable quartz.

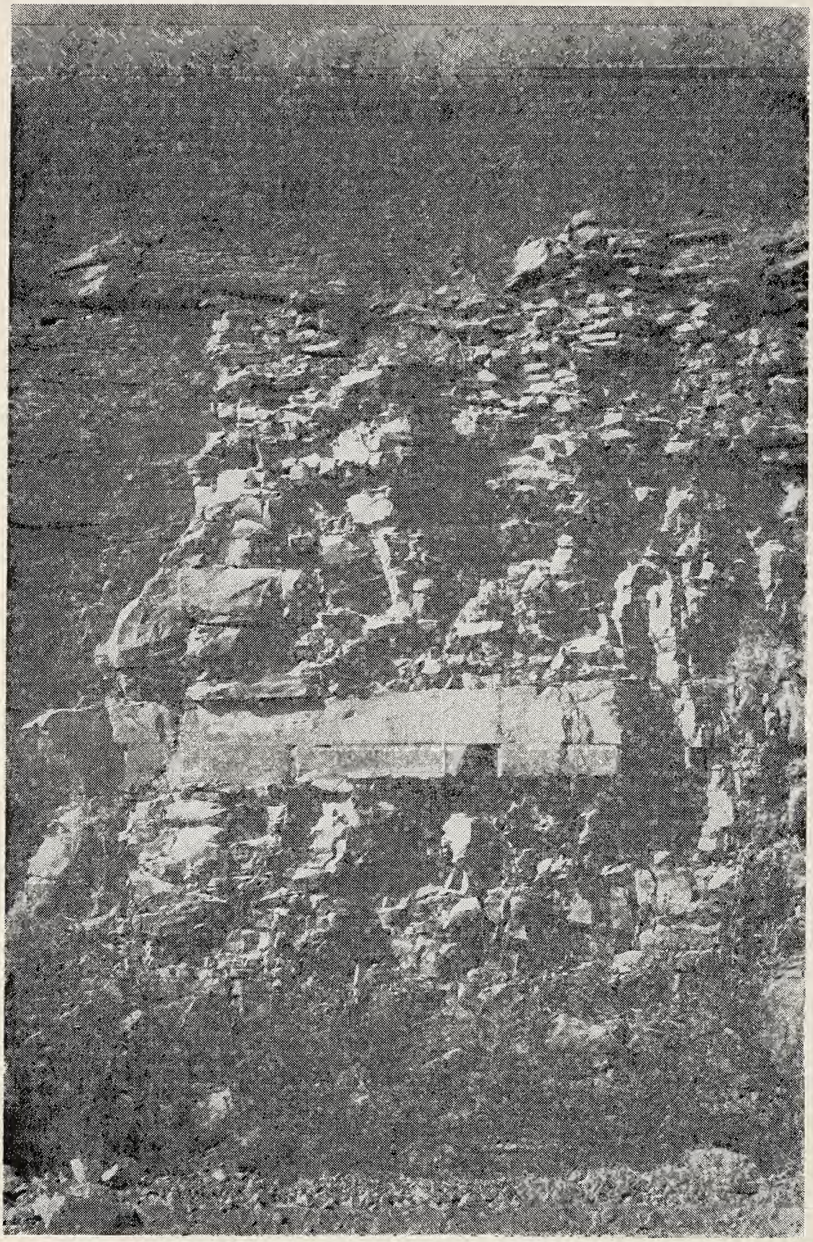

FIGURE 10. DeCew-limestone " lentil " sequence at type section of " lentil " southeast of Brockport. Upper thick bed of DeCew marked by 2-foot tape.

Contacts. An interbedded lower contact with the DeCew is present in the Brockport quarry, where " enterolithic " dolomite alternates with limestone beds. The contact is drawn arbitrarily above the uppermost massive dolomite bed that persists across the main part of the quarry (see figure 10). On first examination, the contact appears sharp and to be marked by a shaly parting. However, the limestone extends below this parting in places. Just above the parting is a zone of intraformational conglomerate containing rounded, dolomitic pebbles of a DeCew-like lithology. The occurrences of several similar conglomerate zones above suggests that the lower zone is not particularly significant. The writer believes that the contact is conformable. The upper contact is not exposed.

Paleontology. The well-preserved fauna of the " lentil " is essentially one of trilobites and brachiopods. *Stegerhynchus neglectum* and *Fardenia? decewensis* are the predominant brachiopods. *Dalmanites limulurus* and *Trimerus delphinocephalus* are profuse, especially in the lower part. *Homalonotus sp.* has been identified by H. B. Whittington, who believes there may be only one other report of this genus in New York.

A list of those species found in the unit, primarily at the type section, follows:

- Conularida
  - *Conularia niagarensis* Hall
- Bryozoa
  - *Hallopora elegantula?* (Hall)
- Brachiopoda
  - *Leptaena " rhomboidalis "* (Wilckens)
  - *Lingula lamellata* Hall
  - *Rhipidomella hybrida* (Sowerby)
  - *Rhynchotreta americana* Hall
  - *Stegerhynchus neglectum* (Hall)
  - *Fardenia? decewensis* Williams
  - *S. patenta* (Hall)
  - *S. striata* (Hall)
  - *Whitfieldella nitida* (Hall)
- Gastropoda
  - *Hormotoma* cf. *subulata* (Conrad)
  - *Platyceras niagarense* (Hall)
- Trilobita
  - *Dalmanites limulurus* (Green)
  - *Homalonotus sp.*
  - *Trimerus delphinocephalus* Green

Comments. Although the fossils are no more indicative of the Lockport than of the Clinton, the limestone " lentil " is placed in the Lockport for the following reasons:

(1) Stratigraphic position above the DeCew;
(2) Presence of crinoidal beds that suggest a lateral equivalence with the Gasport;
(3) Lithology and bedding characteristic of the Lockport.

In the same stratigraphic position in the Spencerport $7\frac{1}{2}$-minute quadrangle (NE $\frac{1}{4}$ of Bergen quadrangle) is a crinoidal reefy lithology that represents the transition zone between the Gasport, limestone " lentil " and other lower Lockport units to the west and the Penfield Member to the east.

GOAT ISLAND MEMBER

Name and type section. This member was renamed by Howell and Sanford (1947, p. 34) for that portion of the Lockport sequence between the Gasport and Eramosa in western New York. Because the previous name, Suspension Bridge, was preoccupied, they proposed the new name, Goat Island, for exposures on the small island on the brink of Niagara Falls. Their choice of a type section was a poor one; it is practically inaccessible. Better sections were available at the time, on both the Canadian and United States sides of the gorge. It was also unfortunate that Howell and Sanford failed to describe the member.

Extent and thickness. The member extends from the vicinity of Hamilton, Ontario, eastward through the Albion quadrangle in New York State. At localities 2 and 3 near Niagara Falls, the measured thicknesses are 19 and 25 feet respectively. Generally, it appears that the Gasport and Goat Island sequence is fairly constant in thickness along the gorge; thus, where one thins, the other thickens.

Bolton's statement (1957, p. 50) that the range in thickness of the Goat Island at Niagara is from 31 to 52 feet is questionable in view of the fact that in three of his cores the member was reported as being 20 feet thick or less. At Medina (loc. 43), the member is about 20 feet thick, whereas at least 25 feet are present at Clarendon (loc. 57).

Lithologic description. Owing to the inadequacy of the type section for detailed study, the writer proposes as a reference section the exposure along the south haul road (loc. 2; see figure 5). The sequence is accessible there, and both lower and upper contacts are exposed. The Goat Island at the reference section is light olive-gray to brownish-gray, medium-grained, thick-bedded, saccharoidal dolomite. Chert nodules are abundant at the top in a thin zone that continues upward into the basal part of the overlying Eramosa. Sporadic nodules were observed in the lower part of the unit south of Lewiston (loc. 1). Stylolites and carbonaceous partings are abundant. Vugs, limited to zones, contain gypsum, dogtooth spar, and sphalerite.

Exposures are rare east of Niagara Falls. At the Frontier Dolomite quarry (loc. 29) near Lockport, the member includes light, saccharoidal dolomite containing stromatoporoids, overlain by darker, medium-bedded dolomite. Along Oak Orchard Creek (loc. 43), the member is brownish-gray, medium-grained, thin- to medium-bedded dolomite. The easternmost exposure of typical Goat Island is at the Clarendon Stone quarry (loc. 57) in the Albion quadrangle. There, immediately overlying the Gasport, is olive-gray, medium-grained, medium-bedded dolomite containing an abundance of chert nodules. Upward, the strata become darker, coarser, and less cherty. Crinoidal beds are common in the upper part.

Microscopic petrography. A thin section of a specimen from the exposure along the south haul road (loc. 2) shows an equigranular dolomite consisting of subhedral grains between .06 and 0.2 mm. in size. The texture, typical of most dolomites, is interlocking. Secondary dolomite euhedra occur in veinlets and in small vugs. Most of the grains are brownish in plane polarized light. This is believed to be due to the inclusion of argillaceous and organic matter in the dolomite. Thin stringers of corroded dolomite grains enclosed in an argillaceous matrix are common.

Insoluble residues. The Goat Island is a low-insoluble unit. Four samples between Niagara Falls and Medina averaged 2.9 percent insoluble. The sequence at Clarendon (loc. 57) is more impure. The lower chert-bearing beds are about 7 percent insoluble; the upper crinoidal strata, about 11 percent. Quartz and a clay-sized fraction are the main constituents of the residues.

X-ray diffraction. The analysis of a specimen from unit 9 at the reference section (loc. 2) is believed to be representative of the member in that the carbonate is wholly dolomite. Field observations indicate that there is little, if any, limestone in the Goat Island.

Contacts. The lower contact with the Gasport, as mentioned previously, is conformable. The contact with the overlying Eramosa is conformable also. This upper contact was exposed at several places in the power project excavations. At the south haul road (loc. 2), it is marked by a shaly, limonitic parting. Groundwater is emitted at the contact and undoubtedly accounts for the staining. The dolomite is slightly bituminous just above the parting. Chert nodules are present both above and below the contact at this locality. The only exposure of the upper contact east of Niagara Falls is on Oak Orchard Creek (loc. 43), where the Goat Island grades upward into the Oak Orchard Member.

Paleontology. Fossils are not common and are poorly preserved. Brachipods, stromatoporoids, and corals are the most abundant groups. The species found include *Enterolasma caliculum, Leptaena "rhomboidalis," Protomegastrophia profunda, Stegerhynchus acinus,* and *Whitfieldella nitida.* The chert nodules in the upper part of the member, as well as in the basal Eramosa, contain well-preserved silicified fossils. The best collecting is from the loose blocks at the foot of the observation tower by the American Falls. Although the fossils belong to both the uppermost Goat Island and the lowermost Eramosa, they are presented here arbitrarily.

- Stromatoporoidea
  - *Ferestromatopora* sp.
  - *Stromatopora?* sp.
- Anthozoa
  - *Enterolasma caliculum* (Hall)
  - *Favosites* sp. A.
- Bryozoa
  - *Chasmatopora asperatostriata* (Hall)
  - *Chilotrypa?* sp.
  - *Hallopora* sp.
- Brachiopoda
  - *Cyrtina pyramidalis* (Hall)
  - *Leptaena "rhomboidalis"* (Wilckens)
  - *Hedeina crispa* (Linnaeus)
  - *Stegerhynchus neglectum* (Hall)
  - *Trematospira camura* (Hall)
- Gastropoda
  - *Hormotoma* sp.
  - *Platyceras niagarense* (Hall)
  - *Poleumita scamnata* Clarke and Ruedemann
- Trilobita
  - *Calymene* sp.
  - *Dalmanites limulurus* (Green)

Comments. The lower strata of the Goat Island in the Niagara Peninsula of Ontario are characterized by an abundance of chert nodules. This chert-bearing sequence is referred to informally as the Ancaster chert beds. The cherty beds in the lower part of the Goat Island at Albion (loc. 57) are probably equivalent to the Ancaster beds in Ontario.

So far as can be determined, the " lower Shelby dolomite " along Oak Orchard Creek (Clarke and Ruedemann, 1903) is in the upper part of the Goat Island Member as defined by this writer.

The relatively high proportion of insolubles at Clarendon, and the presence of crinoidal beds, reflect the beginning of an eastward transition to the crinoidal and quartzose Penfield Member.

ERAMOSA MEMBER

Name and type section. Williams (1915b) proposed the name " Eramosa " for the upper beds of the Lockport in southwestern Ontario. The type section is along the Eramosa River between Rockwood and Guelph.

Extent and thickness. The member extends only into the Tonawanda-Lockport area in New York State. Other geologists (Chadwick, 1918; Reed, 1936), however, believed that the unit is present at Rochester. The Eramosa in the Niagara Falls-Tonawanda quadrangles is from 16 to 18 feet thick. It caps the falls at Niagara.

Lithologic description. The Eramosa is medium dark-gray to dark-gray, fine-grained, thin- to medium-bedded, argillaceous and bituminous dolomite. It weathers a distinct light gray, presumably because of the argillaceous content. Most of the bedding and parting surfaces are coated with carbonaceous shale. Chert is present in the basal bed along the south haul road (loc. 2). Stylolites are not common. Vugs contain a variety of minerals, such as dogtooth spar, gypsum, sphalerite, and galena.

Microscopic petrography. Under the petrographic microscope, the Eramosa is seen to have an equigranular texture that consists of subhedral to anhedral dolomite grains averaging .04 mm. in greatest dimension. Detrital quartz is second in abundance. Many dolomite grains have hazy boundaries owing to their corrosion by the argillaceous matter that " cushions " them. Pyrite is disseminated through the section. Relicts of crinoid columnals are distinguishable (see figure 11).

Insoluble residues. With the exception of the lower chert bed, insoluble residues are relatively high, averaging about 18 percent.

The residues are subdolomoldic and consist chiefly of quartz and clay. A bituminous content was indicated both by the odor emitted when the rocks were crushed and by the presence of an oily film on the beaker when the samples were acidized.

X-ray diffraction. The Eramosa is noncalcareous, the carbonate fraction being exclusively dolomite. A strong peak at $2\theta = 27°$ indicates a considerable quartz content. This implies that much of what is considered as " argillaceous " in the hand specimen is actually very finely divided quartz. That some argillaceous or micaceous matter does occur in the matrix, however, is revealed by a small peak at $2\theta = 9°$.

Contacts. The lower contact with the Goat Island is believed to be conformable (see discussion of that unit). The upper contact with the Oak Orchard is sharp but conformable. The light-weathering, thin- to medium-bedded Eramosa is overlain by brown, massive, bituminous, very vuggy dolomite that is the basal Oak Orchard. Limonitic stains at this contact (loc. 3) probably are not significant. The writer attributes this coloration to groundwater that, having dissolved iron-bearing minerals (e.g., pyrite) as it migrated downward through the overlying vuggy stratum, subsequently deposited them on issuing forth at the contact with the less permeable Eramosa.

Paleontology. In addition to the fossiliferous chert zone in the upper Goat Island-lower Eramosa interval, this member has a rare but distinct noncoelenterate fauna.

- Brachiopoda
  - *Atrypa reticularis* (Linnaeus)
  - *Lingula lamellata* (Hall)
  - *Stegerhynchus acinus* (Hall)
  - *S. neglectum* (Hall)
- Gastropoda
  - *Ectomaria*? cf. *galtensis* Billings
- Cephalopoda
  - *Dawsonoceras americanum* (Foord)
  - *Kionoceras darwini* (Billings)
  - *Lechritochoceras desplainense*? (McChesney)
  - *Protokionoceras*? *trusitum* (Clarke and Ruedemann)
- Trilobita
  - *Dalmanites limulurus* (Green)

Although the trochoceroid genus *Lechritochoceras* is known from the Clinton Group (Flower, 1942, pp. 24–26), it is more characteristically a Guelph element.

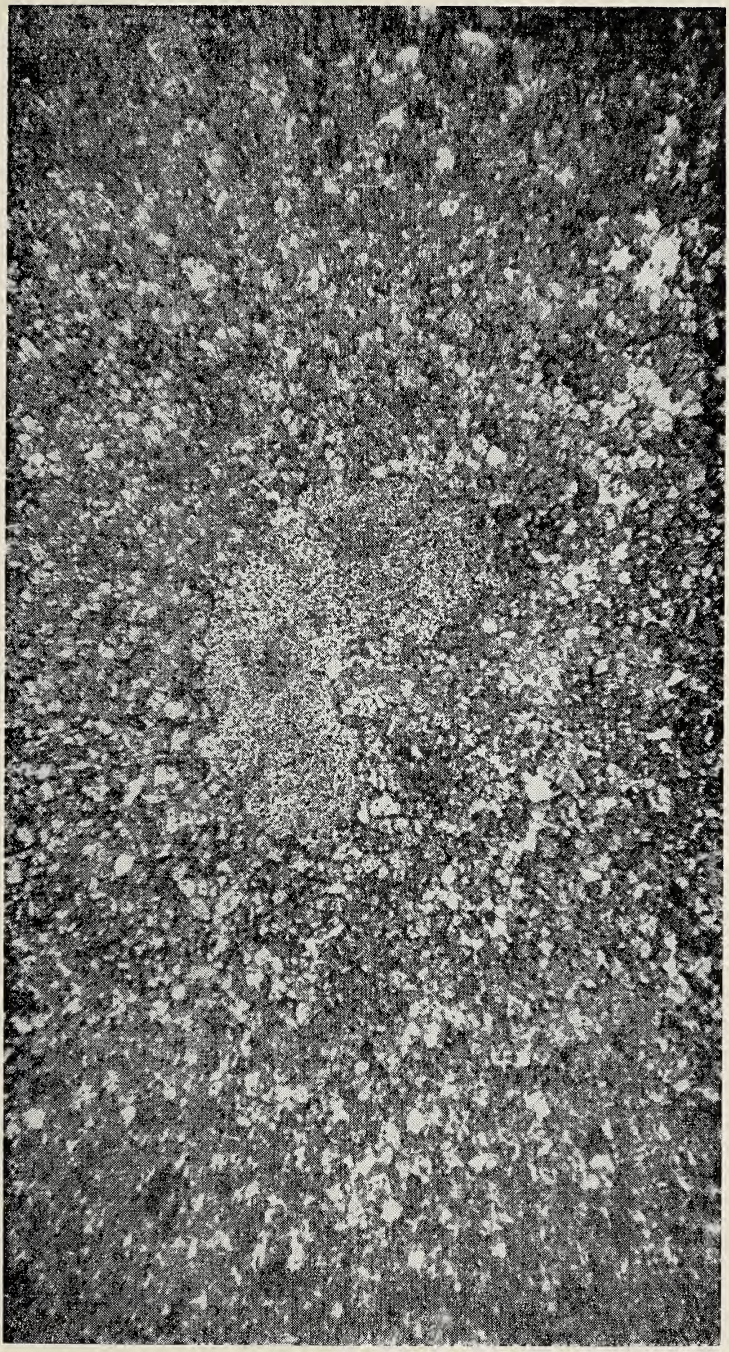

FIGURE 11. Photomicrograph. Fine-grained Eramosa at Niagara Falls. Note relict pelmatozoan columnal (plane polarized, X40).

Comments. The Eramosa has been traced by other workers from its type area into Niagara Falls. The thin-bedded, argillaceous, and bituminous nature persists into New York but the unit is much thinner. The rock at Niagara is darker and finer grained than that seen by this writer in the vicinity of Dundas and Hamilton, Ontario. Some parts of the unit in Ontario resemble the Oak Orchard Member of the Lockport. The section along Oak Orchard Creek (loc. 43) includes a sequence of the Lockport from the DeCew into the Oak Orchard. The insolubles are low throughout, and there is no suggestion of the Eramosa lithology as is present at Niagara Falls.

OAK ORCHARD MEMBER

Name and type section. Howell and Sanford (1947, pp. 33–34) proposed " Oak Orchard " for the upper part of the Lockport in western New York. The name was applied to the sequence along Oak Orchard Creek that had been called the Shelby (name preoccupied) beds by Clarke and Ruedemann (1903). Unfortunately, for reasons to be presented later, this locality was chosen as the type section by Howell and Sanford. In an effort to keep new nomenclature at a minimum, the name " Oak Orchard " is retained but the unit is redefined because of some common misconceptions. Three localities, two of them in the west-central area, serve as reference sections: the Niagara Stone quarry (loc. 9, Tonawanda quadrangle), the Barge Canal at Rochester (loc. 82), and Allen Creek in Rochester (loc. 90).

Extent and thickness. The member comprises over half the mass of the Lockport Formation in western New York. It extends across the western and west-central areas. There is no suitably exposed sequence in this western area that would permit a determination of the exact thickness. The thickness at Niagara, based on measurements at the power project, is about 120 feet. The diamond drill core from East Oakfield (loc. 49, boundary of Medina-Albion quadrangles) contains 110 feet of upper Lockport and apparently it is all Oak Orchard. Cannon's descriptions of diamond drill cores in the Medina and Albion quadrangles (1955, pp. 141, 175–176) are interpreted by this writer as showing about 140 feet of Oak Orchard. The member extends westward into Ontario, where it is called the Guelph Formation. However, east of Hamilton, in the Niagara Peninsula of Ontario, this " Guelph " is closer lithologically to the Oak Orchard than to the buff, saccharoidal dolomite of the true Guelph.

Lithologic description. Except for the exposures in the power project (locs. 2–7) and in the Niagara Stone quarry (loc. 9), outcrops of the member in the western area are both few and small. Excavations in the power project provided an almost continuous section from the lower contact with the Eramosa to within 20 feet of the Salina. Unfortunately, most of these sites have been filled and are no longer available for study. The member in the Niagara area is, in general, brownish-gray to dark-gray, fine to medium-grained, thin- to mostly thick-bedded, saccharoidal, bituminous dolomite. Stylolites, carbonaceous partings, and vugs are common. Ripple marks were observed on some bedding surfaces. Darker laminations and bands, some inclined to the bedding, are present in various intervals throughout. Brownish-gray, porous, sandy-textured pockets are characteristic of some zones. Conspicuous reentrants have formed through the weathering of shaly bedded, finer-grained, less-resistant dolomite.

Hemispherical masses called stromatolites (see section on Stromatolites for more detailed treatment) occur in two zones at Niagara Falls. In the lower zone (unit 6, loc. 4; unit 3, loc. 9), these structures are discrete bodies, 4 to 10 feet across, with thinner-bedded dolomite arched over them. A *Favosites* biostrome overlies this lower zone in the Niagara Stone quarry. In the upper zone (unit 5, loc. 7), the stromatolites are domal structures consisting of arched, superimposed plates from 4 to 5 feet across. Intraformational conglomerates and oolites are associated with the stromatolites.

Scattered exposures elsewhere in the Tonawanda quadrangle show the general characteristics mentioned. Exposures and dumps along the Barge Canal, in the Lockport quadrangle, provide fragmentary glimpses of the Oak Orchard stratigraphy. Stromatolitic domes and blocks of bituminous dolomite containing intraformational conglomerates, oolites, and leperditiid ostracodes constitute most of the dump piles near the southern margin of the outcrop belt south of Lockport. Contrary to previous implications (Clarke and Ruedemann, 1903; Howell and Sanford, 1947; and others), only the lower part of this member is exposed along Oak Orchard Creek, the designated type section. There, the basal part is coarsely grained, hematitic, and fossil fragmental. This interval may represent a condensed unit to be correlated with the missing Eramosa (Cannon, 1955, p. 142), but the evidence is not conclusive. The overlying part, less than 15 feet thick, is much like the Oak Orchard at Niagara Falls, except for the presence of light-gray chert nodules. The diamond drill core from East Oakfield (loc. 49) shows the dark brownish-gray, saccharoidal, stylolitic dolomite that is typical of the member. Intervals packed with small, dolomitized, bryozoan-like bodies, which probably are specimens of *Cladopora,* are present in the lower part of the core. There are very few outcrops of the Oak Orchard in the Albion and Bergen quadrangles. Glacial boulders from the member litter the fields and they commonly consist of dark brownish-gray, saccharoidal, bituminous, vuggy dolomite. Many of these blocks contain the dolomitized remains of corals and stromatoporoids. Dolomite, calcite, galena, and gypsum are abundant in vugs and veinlets.

Microscopic petrography. Several thin sections of the Oak Orchard were studied; they possess certain features in common. The texture commonly is interlocking and equigranular, consisting of subhedral to anhedral dolomite grains that average between 0.1 and 0.2 mm. in size (see figure 12). Darker stringers are composed of smaller dolomite grains (less than .05 mm.) bordered and corroded by argillaceous matter. Microstylolites are very common. Porosity ranges from nearly zero to 25 percent. There are sporadic patches that are coarser grained and more porous than the main groundmass. Most of the dolomite grains are brownish, due to the bituminous content, whereas the clearer areas represent secondary precipitation of sparry dolomite. Ghosts of crinoid columnals and pellets were noted in many sections. Also observed were intraclasts with sharp to hazy boundaries. The instances of transitional or vague boundaries may represent pseudobreccias. Quartz and chert(?) are present but rare. Organic matter commonly is pyritized.

Two sections of the oolitic strata in the upper Oak Orchard at Niagara Falls show different stages in the obliteration of the structures. The oolites range in diameter from 0.25 to 0.8 mm. Although no radial elements were seen, many of the oolite relicts exhibit a faint concentric structure. Pellets and elongate, rounded intraclasts up to 15 mm. in length are associated with the oolites. Microstylolites transect both oolites and intraclasts.

Insoluble residues. The Oak Orchard is a low-insoluble unit throughout. The average insoluble content of 19 samples in the western area is 2 percent and the highest recorded is 7.6 percent. There are no obvious trends either vertically or geographically, except that the stromatolites are slightly less pure. The residues consist of quartz grains less than .04 mm. in greatest dimension, clay, and brownish organic matter. Several acidized samples left only an oily, bituminous scum.

X-ray diffraction. Three analyses of this extensive and thick mass permit only a general statement. The member is essentially a dolomite. Acid tests in the field support this generalization.

Contacts. The lower, sharp, but conformable contact with the Eramosa has been discussed. East of the Tonawanda quadrangle,

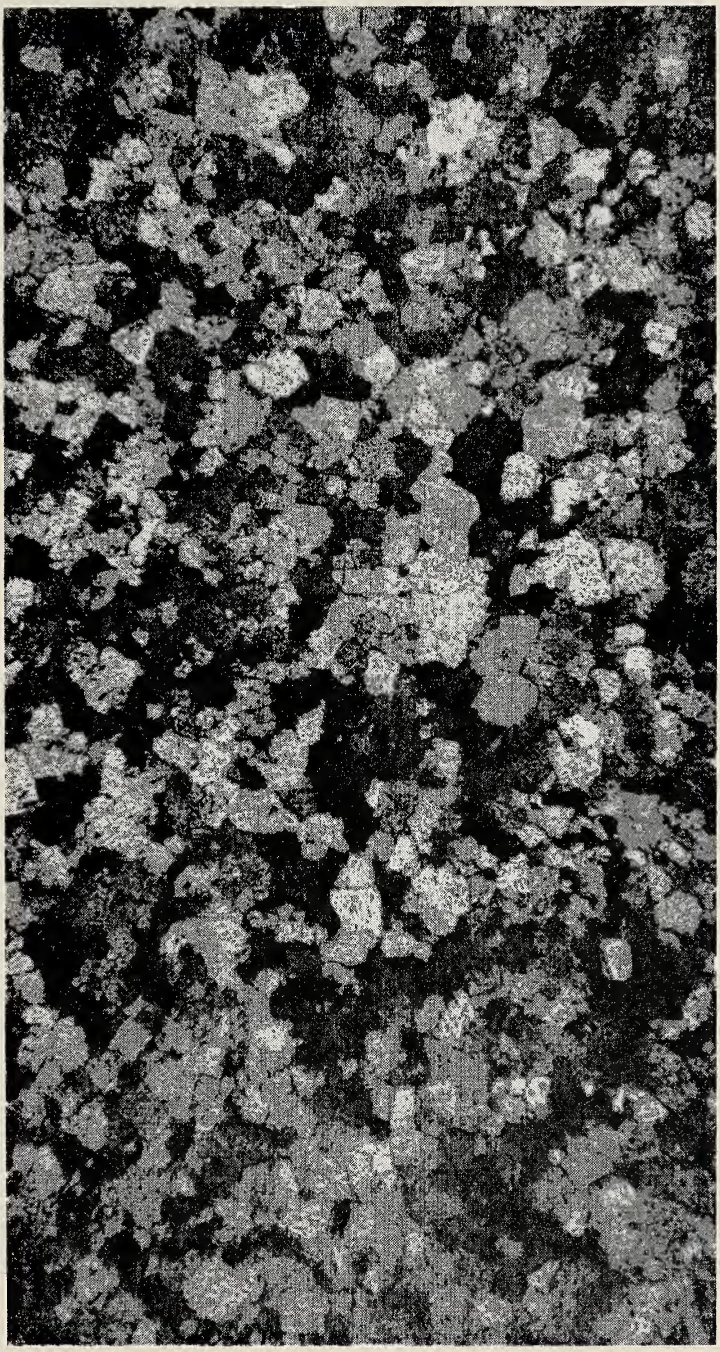

FIGURE 12. Photomicrograph. Lower Oak Orchard Member at Niagara Falls; note interlocking texture (crossed nicols, X30).

the basal contact is with the Goat Island Member and presumably it is transitional, as it is at Oak Orchard Creek (loc. 43). So far as is known by the writer, the upper contact with the Salina is not exposed in the western area. The contact, as revealed in a diamond drill core (loc. 49) south of Albion, is gradational, with a transitional zone of shale and argillaceous dolomite between the Lockport and Salina. Short cores near Niagara Falls (loc. 7a) and south of Lockport (loc. 30a) are from this transition zone.

Paleontology. The sparseness of fossils in the Oak Orchard probably is due to the obliteration of some organic remains during dolomitization. Excluding the stromatolites, corals and stromatoporoids are the prevalent groups. *Favosites* and *Cladopora* are the most abundant coral genera. *Favosites niagarensis* is profuse and well preserved in a biostrome exposed at the Niagara Stone quarry (loc. 9). *Enterolasma, Halysites,* and *Zaphrentis* also are abundant in the member. A bed containing abundant leperditiids, probably *Herrmannina,* is present just above the upper stromatolites at Niagara Falls. Very poorly preserved specimens of *Pterinea* were found above the stromatolites. Blocks containing *Herrmannina* are abundant at a dump along the Barge Canal south of Lockport (loc. 26), just north of another dump containing stromatolites. A poorly preserved steinkern of a pentamerid, possibly *Conchidium,* was collected with *Herrmannina.* The writer has seen loose pieces of the Oak Orchard that contain the gastropod *Coelocaulus.* This genus, together with *Protokionoceras,* may represent Guelph affiliations, although they are not diagnostic of that fauna. The upper Guelph fauna at Oak Orchard Creek (Clarke and Ruedemann, 1903) apparently was taken from the chert zone mentioned previously. Neither the upper nor the lower Guelph faunas were found at this locality, although an intensive search was made. The lower Guelph fauna is believed to be in the upper part of the Goat Island at Oak Orchard Creek. That Guelph forms occur lower than the Oak Orchard Member is suggested by the presence of *Poleumita* and *Lechritochoceras* in the Eramosa at Niagara Falls.

Following is a list of the fossils collected in the western area:

	Localities
Plantae?	
Stromatolites	3, 4, 5, 7, 25
Stromatoporoidea	
Stromatoporoidea indet.	43, float

Anthozoa	
Cladopora multipora? Hall	55
C. seriata?	55
Enterolasma caliculum (Hall)	9, 43
Favosites niagarensis (Hall)	4, 9
F. sp. A	43
F. sp. B	43
F. sp. C	43
F. sp.	43, 49
Halysites sp.	43
Palaeophyllum multicaule (Hall)	43
Zaphrentis bilateralis? Hall	43
Z. sp.	43, 55
Brachiopoda	
Conchidium? sp.	26
Pelecypoda	
Pterinea sp.	7
Ostracoda	
Herrmannina sp.	7, 26

Comments. Since the work of Clarke and Ruedemann (1903), it apparently has been assumed by many (e.g., Howell and Sanford, 1947; Fisher, 1960) that the Oak Orchard Member includes both the upper and lower Shelby beds and not much more. These assumptions have led to certain misconceptions, clarification of which is long overdue. Clarke and Ruedemann, in describing the Guelph fauna, did not consider the two occurrences along Oak Orchard Creek as true lithologic units. Nevertheless, it was implied that they correlated the Shelby dolomites with the Guelph Formation of Ontario. Unfortunately, their note that the southernmost outcrop (i.e., upper Shelby bed) on Oak Orchard Creek is close to the Salina contact was accepted and carried along by other authors. From field relationships, there are nearly 100 feet, stratigraphically, of unexposed Oak Orchard south of this outcrop! Williams (1919, p. 63) found *Monomerella* cf. *orbicularis* in the Eramosa and suggested a correlation with the lower Shelby bed of New York. He regarded the upper Shelby horizon as being in the lowermost Guelph. Howell and Sanford (1947, pp. 33–34) selected their type section on the basis of Clarke and Ruedemann's report, not realizing that more than three-fourths of the member is unexposed there. Fisher (1960) apparently considered the two Guelph horizons to be lithologic units within the Oak Orchard division (i.e., above the Eramosa) and he proposed formal names for them (see also section on previous work).

Field observations at Niagara Falls and at Oak Orchard Creek indicate that the lower Shelby bed is stratigraphically below the Oak Orchard Member. This leaves only the upper Shelby bed in the Oak Orchard. This interpretation supports the suggestion of Williams (1919) just described. In the opinion of this writer, it is very doubtful whether the lower and upper Guelph faunas are continuous horizons. Certainly these zones are not represented by true lithologic units, and thus are not deserving of formal stratigraphic names.

In conclusion, it is believed that the upper Lockport, or Oak Orchard Member, is an indivisible lithologic unit that contains Guelph fossils here and there. Possibly the chert zone, with its Guelph elements, is continuous into the west-central area. It is stressed that the true Guleph lithology of Ontario is not present in New York.

STRATIGRAPHY OF THE WEST-CENTRAL AREA (Rochester through Palmyra quadrangles)

GENERAL

There are many exposures in and adjacent to the Rochester quadrangle. The more important sections are provided by the quarries at Gates and Penfield, the Barge Canal, and Allen Creek (locs. 80, 92, 82, and 90 respectively). There are fewer exposures in the Macedon (excluding loc. 92) and Palmyra quadrangles. The blasting of drainage ditches has provided limited sections. The easternmost active quarry (loc. 117) in the Lockport is located just south of Sodus. Two diamond drill cores (locs. 97a, 117a) were studied from this part of the outcrop belt. The west-central area is defined on the basis of critical changes in stratigraphy at the approximate eastern and western boundaries. Figure 13 is a columnar section of the Lockport in the Rochester-Penfield area.

DECEW MEMBER

Name and type section. See discussion for western area.

Extent and thickness. The member is 12 to 15 feet thick in the Rochester quadrangle. Presumably, it extends eastward into the Macedon quadrangle, although no exposures were seen east of Rochester.

Lithologic description. The DeCew, at Rochester, is olive-gray to brownish-gray, medium-grained, " enterolithic," siliceous dolomite. Cross laminations are apparent on some weathered surfaces. The entire sequence is convolute and has irregular to subconchoidal partings. This " enterolithic " structure is present at every outcrop, particularly good examples being along the Barge Canal and at the upper falls of the Genesee River. Small vugs containing gypsum are present, but rare, in the unit.

Microscopic petrography. The DeCew consists of an interlocking texture of subhedral to anhedral dolomite grains that average about 0.1 mm. in greatest dimension. Angular to subangular quartz grains, which show undulatory extinction, constitute about 30 percent of the thin section studied. Many of the quartz grains are corroded by the dolomite. Organic(?) particles, some of which are pyritized, are scattered through the dolomite.

Insoluble residues. The one sample of DeCew acidized was found to be 27 percent insoluble. Quartz and a smaller amount of argillaceous matter make up the residue.

X-ray diffraction. No studies were made on the DeCew from this area. Acid tests suggest that the carbonate content is primarily dolomite.

Contacts. Before considering the lower DeCew contact, it is appropriate to describe briefly the upper member of the Rochester, the Gates Dolomite. The true nature and distribution of this unit have not been described since it was named the " Gates limestone " by Chadwick (1918, p. 360) for exposures in the Town of Gates, west of Rochester. Chadwick noted ". . . about 20 feet of beds at the top of the Rochester shale which are apparently not present at Niagara and are really a limestone." The Gates is dark-gray, fine-grained, thin- to medium- and even-bedded, argillaceous and siliceous dolomite with much intercalated shale. Laminations and cross laminations are present throughout and bituminous beds were observed in the Gates quarry (loc. 80). Fossils are rare but *Strophonella, Stegerhynchus, Cornellites,* and *Buthotrephis* were collected. One specimen of the unit was acidized and was found to be 26 percent insoluble. The composition of a thin section of the Gates is about 70 percent dolomite, 20 percent quartz, 9 percent argillaceous matter, and 1 percent pyrite, plagioclase, gypsum, and other minerals. Dolomite and quartz grains average about .08 mm. in size. The texture generally is interlocking, except in argillaceous seams.

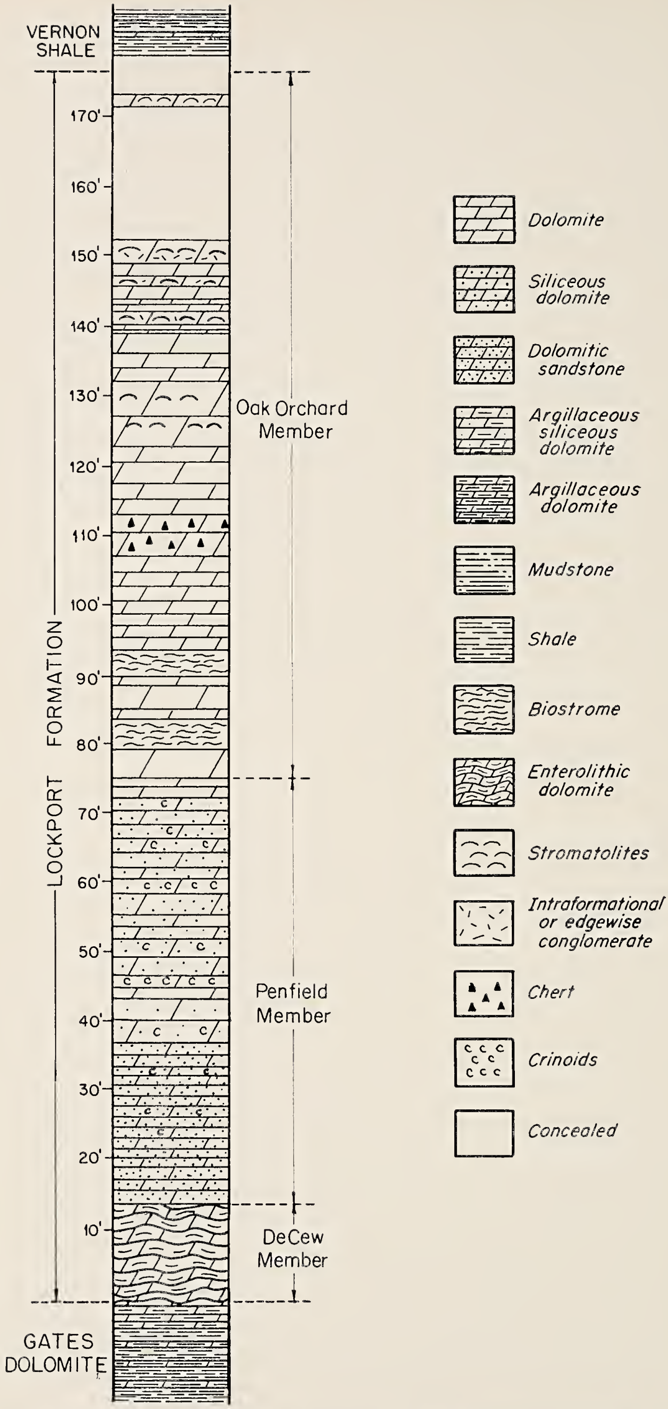

FIGURE 13. Columnar section of Lockport in Rochester-Penfield area.

The lower, shaly portion of the DeCew in the western area was traced eastward to Rochester, where the DeCew itself is coarser and less argillaceous. There is a noticeable similarity between the shaly portion to the west and the argillaceous Gates at Rochester. This situation leads the writer to suspect that the lower, shaly DeCew becomes the distinct Gates in the Rochester quadrangle. The Gates extends into the Palmyra quadrangle.

At Rochester, the convolute DeCew is in contact with the Gates along a wavy surface like that between the DeCew and Rochester Shale at Niagara Falls. The contact appears sharp, but a careful examination shows that lithologically it is gradational. If these contorted structures resulted from a submarine slump, the " channeled " effect in the Gates could have resulted without erosion. The Gates-DeCew contact is considered conformable and the Gates, because of its shaly character, is placed in the Rochester Shale, although it is best regarded as a transition between the Rochester and the DeCew. The uppermost DeCew is transitional to the lower Penfield. Both lower and upper contacts can be seen along the Barge Canal (loc. 82) and in the Gates quarry (loc. 80; see figure 14).

Paleontology. No fossils were collected from the DeCew in the Rochester area.

Comments. The very close relationship between the DeCew and Penfield Members in the Rochester area is indisputable evidence for placing the former in the Lockport at that longitude. The exact eastern limit of the DeCew is unknown. The unit could not be identified in the drill core (loc. 117a) south of Sodus (Palmyra quadrangle), although dolomite beds are present in the upper part of the Rochester Shale. East of Palmyra, where the DeCew is absent and the Lockport thins, the Rochester increases in thickness (Gillette, 1947, p. 101). Although stratigraphic control in this area is slight, it is probable that the upper DeCew grades eastward into the Gates, which this writer considers as the upper part of the Rochester Shale.

PENFIELD MEMBER

Name and type section. Penfield Member was proposed (Zenger, 1962) for the lower part of the Lockport Formation in the west-central area. The type section is at the quarry operated by the Dolomite Products Company, 1 mile north of the village of Penfield

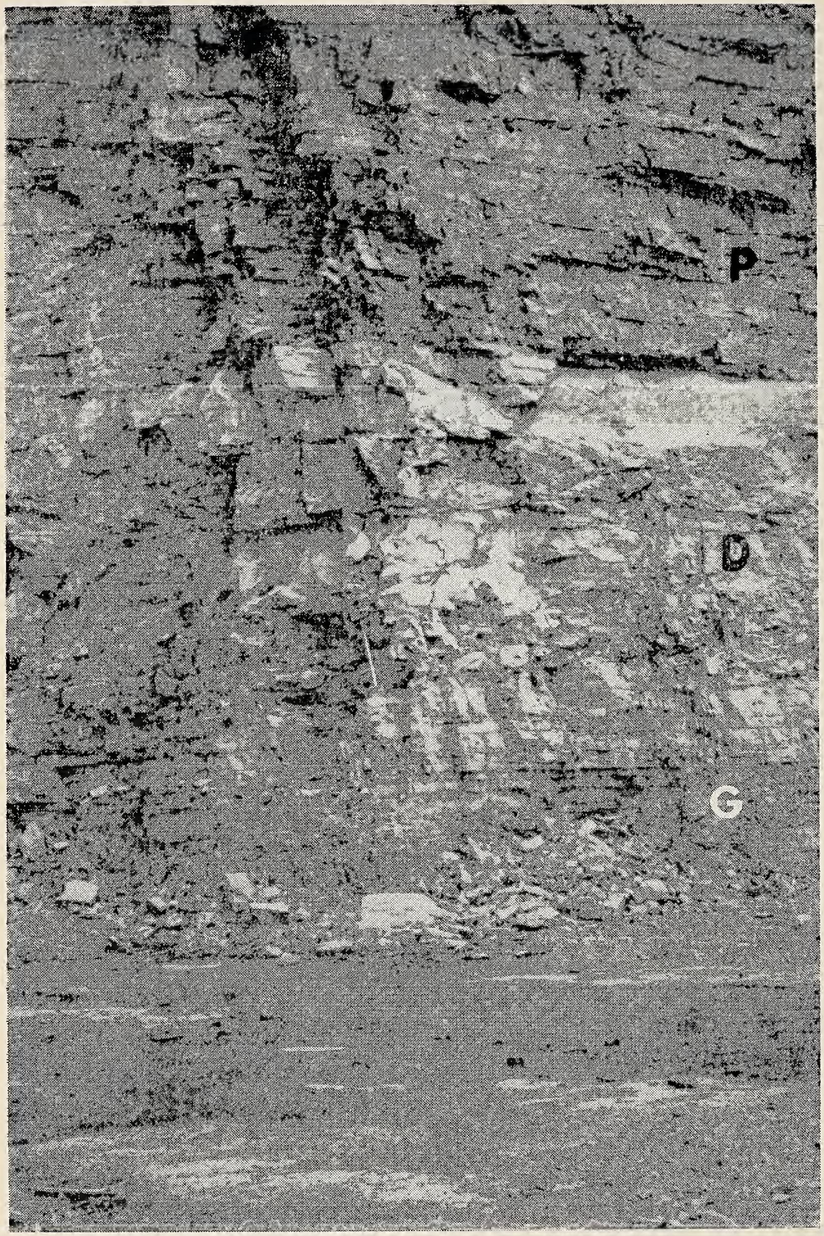

FIGURE 14. Gates (G), DeCew (D), and lower Penfield (P) sequence at Gates quarry just west of Rochester. Sledge marks irregular Gates-DeCew contact.

(Macedon quadrangle, loc. 92), for which the unit is named. Reference sections are in the Gates quarry (loc. 80) and along the Barge Canal (loc. 82).

Extent and thickness. The member extends from Rochester eastward into the Palmyra quadrangle. The crinoidal, biostromal lithology in the eastern part of the Albion and Bergen quadrangles is believed to represent the transition from the lower Lockport in the west to the Penfield. The unit varies in thickness as follows: 52 feet at Gates (loc. 80); 58 feet along the Barge Canal (loc. 82); 54 feet along Allen Creek (loc. 90); and 62 feet at the type section. A complete section is not available east of Penfield. A diamond drill test core (loc. 97a) for a new quarry in the eastern part of the Macedon quadrangle includes 42 feet of Penfield, but the lower contact was not penetrated. The easternmost exposures of typical Penfield are in the western half of the Palmyra quadrangle.

Lithologic description. Crinoid fragments and a high percentage of quartz are the outstanding characteristics of the unit. The basal part is actually dolomitic sandstone. Above this sandstone, the quartz content is less than 50 percent and the strata are quartzose dolomites. With the exception of Hall (1843, p. 87), few have mentioned this peculiarity of the Lockport in the Rochester area. The lower dolomitic sandstone is medium gray to light gray, medium grained, and medium bedded. Laminations, carbonaceous partings, cross stratification, and microstylolites are common. In the Gates quarry, and along the Barge Canal, the bedding is slightly contorted just above the DeCew. The quartzose dolomites overlying the sandstone are medium dark gray to dark brownish gray, and in this respect resemble the Oak Orchard. The grain size averages between 0.1 and 0.2 mm., although there are sporadic finer-grained beds, as well as coarser-grained layers containing large fragments of crinoids. Conglomeratic, fossil-fragmental zones were observed east of Rochester.

The bedding ranges from thin to thick and massive. Laminations and bands of alternating shades of brown are visible on weathered surfaces. Coarser, porous, sandy-textured patches and lenses are common in the upper half of the unit. Generally, the Penfield is much less bituminous than the overlying Oak Orchard Member. Several sections contain strata characterized by small voids and indistinct bedding. Although fossils rarely are discernible, these beds probably represent biostromes. Vugs are present throughout, but they are most abundant in the upper part. Dolomite, sphalerite, gypsum, and selenite are found in these cavities.

Microscopic petrography. Three thin sections of the Penfield were studied: one from the lower sandstone unit at the type section (loc. 92), one from unit 5 at the same locality, and one from an outcrop (loc. 106) in the Palmyra quadrangle.

The dolomitic sandstone has an equigranular texture of quartz and dolomite grains, which average between 0.12 and 0.17 mm. in greatest dimension. The quartz is strained and commonly corroded by the dolomite. Many of the quartz grains are in contact, and in these instances they are cemented by secondary silica. Microstylolites transect dolomite and quartz grains indiscriminantly. Zircon, plagioclase, amphibole, and gypsum were noted. The siliceous dolomites also are equigranular with interlocking texture. The subhedral dolomite grains and the subangulor quartz grains have about the same size, between 0.1 and 0.2 mm. The quartz shows undulatory extinction. Where the quartz grains are not in contact, they " float " in the dolomitic groundmass. In mottled areas, the dolomite grains are cushioned in argillaceous matter. Black, opaque organic bodies, remnants of fossils, chert, and zircon also are present.

Insoluble residues. The Penfield is one of the high-insoluble (averages more than 15 percent insoluble) members of the Lockport. The insoluble content of 8 samples ranged from 4.3 to 61.1 percent, and averaged about 30 percent, the lower sandstone being the most insoluble. The residues generally are free of organic matter. Clear quartz, as silt and fine sand, and a minor amount of pyrite constitute the residues.

X-ray diffraction. Analyses of samples from units 1 and 7 at the Penfield quarry support field and other laboratory observations. Calcite was not detected in any appreciable amount; quartz is the chief impurity. In the Penfield Member, then, we have an exception to the generality that the impure carbonate rocks tend to be mixed carbonates (Steidtmann, 1917, p. 436; Dunbar and Rodgers, 1957, p. 223).

Contacts. Both lower and upper contacts are conformable and gradational. The siliceous dolomite of the DeCew grades upward into the dolomitic sandstone of the Penfield. In several sections, the convolute bedding continues into the lower Penfield and is reflected by the subconchoidal partings. The lower contact is exposed in the Gates quarry (loc. 80; see figure 14) and along the Barge Canal (loc. 82), although it is not easily accessible at either place. The upper contact with the Oak Orchard is exposed at the two localities just mentioned and at the type section of the Penfield (loc. 92). The contact is arbitrarily drawn above the uppermost siliceous, crinoidal bed. In most sections, the contact is not well defined and consists of an interval of transition. The insoluble content falls rapidly across the boundary, but unfortunately this is not readily discernible in the field. Although the Oak Orchard is more bituminous throughout than the Penfield, this is not a valid criterion for the establishment of the contact because of the presence of bituminous rocks in some intervals of the Penfield.

Paleontology. Few fossils were collected in the Rochester area because of the inaccessibility of much of the section for other than lithologic sampling. Table 3 presents a list of the fossils collected. The general impression of the writer is that fossils are rare, but again this may be related to the very poor preservation. *Enterolasma caliculum, Cystiphyllum niagarense?, Zaphrentis bilateralis?, Cladopora* sp., *Dawsonoceras americanum,* and *Protomegastrophia profunda* were seen at the Gates quarry. With the exception of *Cystiphyllum,* the same corals were found along the Barge Canal. There are fossiliferous localities (e.g., locs. 96, 115) farther to the east in the Macedon and Palmyra quadrangles, where excavations from deepened drainage ditches afford better collecting (loc. 115, in the Palmyra quadrangle is in a transition zone with units to the east; it is listed arbitrarily with the Penfield). *Howellella* is present in the eastern Penfield (locs. 110 and 115). Apparently, stromatoporoids are extremely rare in the member.

Table 3. Distribution of Penfield fossils

Fossils	Localities								
	58*	71*	73*	80	82	96	106	110	115**
Stromatoporoidea									
Anostylostroma sp.	X								
Parallelopora cf. *ostiolata* Bargatsky	X								
Stromatoporoidea indet.		X							
Anthozoa									
Cladopora multipora? Hall		X							
C. sp.				X		X			
Cyathophyllum sp.						X			
Cystiphyllum niagarense? (Hall)				X					
Diplophyllum caespitosum Hall		X							
Enterolasma caliculum (Hall)				X	X		X		X
Favosites sp. A	X	X							
F. sp. B							X	X	X
Halysites agglomerata Hall	X								
H. sp.			X				X		
Heliolites sp.	X								
Zaphrentis bilateralis? (Hall)				X	X				
Z. sp									
Brachiopoda									
Atrypa reticularis (Linnaeus)							X		X
Hedeina crispa (Linnaeus)									X
Howellella sp. A									X
H. sp. B								X	

Table 3. Distribution of Penfield fossils (Concluded)

Fossils	Localities								
	58*	71*	73*	80	82	96	106	110	115**
H. sp. C								X	X
Leptaena "rhomboidalis" (Wilckens)									X
Parmorthis elegantula (Dalman)									X
Protomegastrophia profunda (Hall)				X					X
Stegerhynchus cf. *acinus* (Hall)							X		
Strophonella striata (Hall)							X		
S. sp.				X			X		X
Whitfieldella nitida (Hall)									X
W. oblata? (Hall)									X
Pelecypoda									
Leiopteria? subplana (Hall)							X		
Gastropoda									
Naticonema hemisphericum (Hall)							X		
Platyceras sp.									X
Cephalopoda									
Dawsonoceras americanum (Foord)				X					
Trilobita									
Dalmanites limulurus (Green)							X		
Encrinurus sp.								X	
Proetus? sp.							X		

* In zone of transition from lower Lockport to west.
** In zone of transition to Sconondoa Member.

Comments. The Penfield is roughly equivalent to the Gasport, Goat Island, and Eramosa Members in western New York. It has been pointed out that there is no support for the continuation of the Eramosa Member east of the Tonawanda quadrangle, although Chadwick (1918) and Reed (1936) claimed to have recognized the unit at Rochester. Their " Eramosa " would be in the upper Penfield as used by this writer. It is very doubtful whether the Penfield can be subdivided. The typical Penfield is not exposed east of the Williamson 7½ minute quadrangle (Palmyra quadrangle). The sparsity of the field exposures permits only speculation regarding the reason for disappearance. The section and drill core at the General Crushed Stone quarry (locs. 117, 117a) south of Sodus, show that some of the interval occupied by the Penfield to the west is replaced by the Oak Orchard lithology. The relations are not, however, this simple, for at some localities (e.g., loc. 115) there is an interfingering with the Sconondoa Member. Once again, it is noteworthy that the Rochester Shale thickens east of Sodus (Gillette, 1947, p. 101). It is suggested that the Penfield passes eastward partly into the lower Oak Orchard and lowermost Sconondoa (see Plate I) and partly into the Rochester Shale.

OAK ORCHARD MEMBER

Name and type section. See discussion for western area.

Extent and thickness. The member continues eastward from the western area and definitely extends as far east as the Clyde quadrangle (loc. 121). About 80 feet were measured along the Barge Canal (loc. 82), but the upper part is not exposed. Along Allen Creek (loc. 90), where there are isolated outcrops throughout the interval, the unit is about 100 feet thick. Probably 130 to 140 feet are present in the eastern part of the Palmyra quadrangle, where the typical Penfield lithology has disappeared.

Lithologic description. The lithology, similar to that in the western area, consists of brownish-gray to brownish-black, medium-grained, medium- to thick-bedded, saccharoidal dolomite. Most of the bedding surfaces are uneven. Stylolites, shaly partings and stringers, and vugs are ubiquitous. Bands, laminations, and cross laminations commonly were seen on weathered surfaces. There are small zones, or pockets, of brownish-gray, porous dolomite in some beds. Much of the sequence is bituminous. Biostromal beds are not uncommon and contain corals and stromatoporoids in the typical poor state of preservation. Very vuggy layers probably represent dolomitized, weathered biostromes. The two biostromes in the upper part of the Penfield quarry (loc. 92) are vuggy and contain an abundance of secondary minerals.

Chert nodules are present along the Barge Canal (loc. 82), at outcrops in Rochester (locs. 87, 89), and in the Palmyra quadrangle (loc. 114). The three occurrences in the Rochester quadrangle undoubtedly represent the same zone, but more control is necessary before the exact relationship with the chert in the Palmyra quadrangle can be established.

Stromatolites are exposed along Allen Creek (loc. 90) and in a drainage ditch (loc. 102) in the Macedon quadrangle. Intraformational conglomerates are associated with the structures at both localities, but oolitic beds were observed only at the second one.

Peculiar " silt and clay " bands are present in the Oak Orchard at the Sodus quarry (loc. 117). These bands generally parallel the bedding. X-ray diffraction analysis of the " silt-clay " layer in unit 8 shows a composition of quartz and calcite. The sequence in which these layers are found is a low-insoluble dolomite. The origin of such layers is not immediately clear. Perhaps the present composition resulted from a combination of submarine " weathering " (halmyrolysis) and dedolomitization.

Microscopic petrography. The texture, as revealed by two thin sections, is interlocking except where the grains are "cushioned" in a zone of argillaceous or carbonaceous material. The dolomite grains, excluding those in fracture fillings, average about 0.1 mm. in size. One section is laminated, comprising layers of the typical dolomite texture alternating with porous, coarser, and clearer dolomite. Small spherical areas (.02 to 1.0 mm. in diameter) of microcrystalline dolomite may represent pellets. Quartz grains constitute less than 2 percent of the sections.

Insoluble residues. As in the western area, the Oak Orchard is an almost pure carbonate rock that averages less than 2 percent insoluble. It may be significant that the highest insoluble percentage, 4 percent, was found in a specimen from a stromatolitic bed at Allen Creek. The reader is reminded that, at Niagara Falls and Lockport, the stromatolites are characterized by a slightly higher-than-average insoluble fraction. Quartz, as silt grains, and brownish, organo-argillaceous matter make up most of the residues.

X-ray diffraction. From all indications, the Oak Orchard is true dolomite.

Contacts. The Penfield-Oak Orchard contact is exposed at several places (locs. 80, 82, 92) and is included in one diamond drill core (loc. 97a). The contact is gradational from the crinoidal, high-insoluble Penfield to the low-insoluble Oak Orchard (see also discussion for Penfield Member).

The upper contact with the Vernon Shale is not exposed. Along Allen Creek in Rochester (loc. 90), there is covered interval of only 5 feet, stratigraphically, separating the uppermost stromatolite bed of the Oak Orchard from olive-gray mudstones and platy, laminated shales of the Salina. A core drilled near Cuylerville in Livingston County, 25 miles south of Rochester, penetrated the Vernon-Oak Orchard contact. The lowermost Vernon is dark greenish-gray to greenish-black dolomitic shale. The basal inch contains thin, wavy, shaly partings. The uppermost Oak Orchard consists chiefly of dark-gray, very fine-grained, argillaceous and bituminous dolomite and intercalated greenish-black dolomitic shale. This sequence indicates that, although the contact is easily placed, the upper part of the Lockport has an argillaceous character that is very suggestive of a gradation to the overlying Vernon.

Paleontology. The fauna of the Oak Orchard is predominantly one of coelenterates. Corals and stromatoporoids are abundant in biostromes, although typically in a very poor state of preservation owing to recrystallization and replacement. Stromatoporoid biostromes can be seen along the Barge Canal (loc. 82), but are more accessible in the Penfield quarry (loc. 92), where they also contain a profusion of corals, namely *Halysites meandrina*? and *Cladopora multipora*?. A *Favosites* biostrome is present in the upper part of the section at the Sodus quarry (loc. 117). In the Penfield quarry (loc. 92), between the biostromes, is a unit (15) of olive-gray to brownish-gray dolomite containing corals, such as *Favosites* and *Zaphrentis*. Of more significance, however, is the presence in the bed of the leperditiid *Herrmannina* and the spirifer *Howellella*. The chert zone at Rochester is believed to represent Arey's Guelph horizon (1892). As Clark and Ruedemann observed (1903, p. 22):

> " It is to be noted that, while the white chert segregations are in some measure an index of the upper Guelph horizon, those which contain fossils have proved to be in an exceedingly small ratio to the number present. The experience of Mr. Arey in the exposures about Rochester showed that these fossils were to be had only by very great diligence and watchfulness, and it seems probable that they will always be of rarity."

The writer certainly agrees with these observations. Collecting from the chert is very difficult except on weathered surfaces or in excavations where loose pieces are available. The writer found some Guelph(?) mollusks, such as *Kionoceras darwini, Protokionoceras trusitum,* and *Poleumita scamnata,* in the chert. *Monomerella* and *Tremanotus,* which are more indicative of Guelph, were not seen; these probably would turn up under more suitable collecting conditions. *Howellella* and *Pterinea* are associated with the chert at locality 114 in the Palmyra quadrangle. A poorly preserved specimen of *Pterinea* was found in the Oak Orchard at the Sodus quarry (loc. 117). It is noteworthy that this quarry is the easternmost place at which stromatoporoids were seen. Table 4 presents the list and distribution of the Oak Orchard fossils in the west-central area.

Comments. It has been assumed (Clarke and Ruedemann, 1903, and others) that the chert nodules containing the upper Guelph fauna at Oak Orchard Creek represents the same zone as the chert at Niagara Falls and Rochester. The continuity may exist, but an insufficient number of exposures prevents tracing the chert. If there is only one continuous zone, it rises from west to east relative to the base of Lockport. According to Laird (1935, p. 233), the Lockport chert in Ontario formed through a penecontemporaneous replacement of the dolomite. East of the Clyde quadrangle, the Oak Orchard is replaced by the Sconondoa Member.

Table 4. Distribution of Oak Orchard fossils, west-central area

Fossils	Localities								
	80	82	87*	90	92	93	102	114*	117
Plantae?									
Stromatolites				X			X		
Stromatoporoidea									
Stromatoporoidea indet.		X		X	X				X
Anthozoa									
Cladopora multipora? Hall					X				
Enterolasma caliculum (Hall)	X		X			X			
Favosites niagarensis (Hall)							X		X
F. sp. A				X					X
F. sp. C				X	X			X	
F. sp.			X						
Halysites meandrina? (Troost)					X				
H. sp.			X			X			
Zaphrentis raciensis? Whitfield					X				
Z. sp.	X								
Bryozoa									
Hallopora sp.			X						

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* In chert nodules or associated beds

Table 4. Distribution of Oak Orchard fossils, west-central area (Concluded)

Fossils	Localities 80	82	87*	90	92	93	102	114*	117
Brachiopoda									
Coelospira? sp.					X				
Howellella sp. B					X				
H. sp. C					X			X	
Whitfieldella nitida (Hall)			X						
Pelecypoda									
Conocardium sp.			X						
Pterinea sp.								X	X
Gastropoda									
Coelocaulus cf. *vitellia* (Billings)					X				
Hormotoma whiteavesi?								X	
H. sp.								X	
Poleumita scamnata Clarke and Ruedemann			X						
Cephalopoda									
Kionoceras darwini (Billings)			X						
Protokionoceras trustitum (Clarke and Ruedemann)		X							
Ostracoda									
Herrmannina sp.					X				

* In chert nodules or associated beds

STRATIGRAPHY OF THE EAST-CENTRAL AREA (Clyde through Oneida quadrangles)

GENERAL

A scarcity of exposures characterizes the outcrop belt in this area. Bedrock-controlled relief is minimal. Glacial landforms, especially drumlins, produce a rolling topography imposed upon an otherwise monotonous lake plain. Abandoned, water-filled quarries and deepened drainage ditches provide the few outcrops. Although there is poor control on the detailed stratigraphy, there are in this little-studied area some of the keys to the solution of the stratigraphic problems.

SCONONDOA MEMBER

Name and type section. Sconondoa Member was proposed (Zenger, 1962) for the Lockport sequence in the east-central area. The best available type section is along Sconondoa Creek (locs. 152–154) in the eastern part of the Oneida quadrangle. The limestones and dolomites composing the member are well displayed there, but unfortunately these sections are in the zone of eastward transition to the Ilion and there is considerable intercalated shale. The western part of the Sconondoa Member is predominantly limestone with some minor interbedded dolomite, whereas the eastern part is chiefly dolomite. East of Syracuse, the two rock types show a complex facies relationship. There is more limestone than dolomite at the type section but, because of poor control in the Chittenango quadrangle, it cannot be proved that the limestone is continuous from the western part of the Syracuse quadrangle. For these reasons, and because the limestone and dolomite actually have much in common, it is advisable that the entire Lockport Formation in this area be regarded as one member, the Sconondoa, consisting of two facies. The facies are designated informally as the " limestone facies " and the " dolomite facies."

Limestone facies

Reference outcrops. Localities 126 and 130 in the Weedsport and Baldwinsville quadrangles, respectively, serve as reference " outcrops " for this facies.

Extent and thickness. The facies is best developed in the Clyde, Weedsport, and Baldwinsville quadrangles. It also is present in the Syracuse and Oneida areas, but is not exposed in the Chittenango quadrangle. From available data, it appears that most or all of the Lockport Formation in the Weedsport and western part of the Baldwinsville quadrangles belongs to this facies, so the thickness is that of the entire Lockport, between 120 and 150 feet. Eastward, however, sparse outcrops and complex interfingering between limestone and dolomite make untenable any estimate of the thickness of either facies.

Lithologic description. The westernmost appearance of the limestone facies is south of Metz Pond (loc. 118) near the eastern margin of the Palmyra quadrangle, although the calcareous beds just to the west (loc. 115) may represent this facies. The lower part of the Sconondoa is exposed at Metz Pond and also a few miles to the east (loc. 119) in the Clyde quadrangle. The limestone at these places is brownish gray to dark gray, aphanitic, thin to medium bedded, and bituminous. East of Wolcott, in the Weedsport and Baldwinsville quadrangles, the facies is represented by dark-gray to grayish-black, aphanitic to fine-grained, medium-bedded, ripply-fracturing limestone with interbedded shaly limestone and coarser-grained dolomite. Shaly partings, zones containing shale intraclasts, markings (see Comments), and ripple marks were observed. A " pseudo-oolitic " texture composed of small ostracode tests is common.

Stromatolites and associated edgewise conglomerates are abundant east of Baldwinsville. Nowhere are these structures better displayed than along Sconondoa Creek in the Oneida quadrangle (see figure 15). The stromatolites are very similar to those farther west in the Oak Orchard Member.

Microscopic petrography. The very fine-grained to aphanitic texture of the limestone precludes a satisfactory examination in the field, and without a thin-section study of several specimens of the Sconondoa Member many subtle textural characteristics would be unnoticed. Common to most of the sections is an aphanitic calcite groundmass. A specimen of the dense limestone from Metz Pond (loc. 118) has a cryptocrystalline texture. The process of dolomitization is illustrated in this section by laminations of coarser dolomite euhedra grading into the main cryptocrystalline calcite groundmass in which are only sporadic dolomite rhombs.

Examples of replacement were seen in a thin section of mottled dolomitic limestone from the Penfield-Oak Orchard-Sconondoa transition area in the Palmyra quadrangle. The mottles consist of dolomite euhedra in a fine-grained, calcitic groundmass. Between these mottles, dolomite rhombs either replace parts of fossils or " float " in the calcite. Quartzose laminations support the theory of a westward gradation to the Penfield Member. Pellets averaging 0.8 mm. in diameter are abundant in several of the thin sections (see figure 16). These rounded bodies are elongate to rod shaped. They consist of dark, microcrystalline calcite and commonly are not in contact but are surrounded by clear, microcrystalline to fine-grained calcite. Scattered pellets exhibit hazy radial or concentric patterns. Some of these bodies may be oolites, but it is preferable simply to call them "pellets" without genetic implication. Ostracode-rich specimens, when sectioned, show profuse and well-outlined valves. Where the valves are still articulated, they are filled with a fibrous calcite. Associated with the ostracodes are intraclasts and pellets that are embedded in a clearer, fine-grained to microcrystalline calcite cement. There are many instances of dolomite rhombs cutting across ostracode valves (see figure 26). Quartz is rare and "floats" in the calcite groundmass. Small amounts of disseminated pyrite are present in nearly all the sections.

Insoluble residues. The limestone facies between the Palmyra and Oneida quadrangles averages less than 2 percent insoluble. In the eastern half of the Oneida quadrangle, however, the insoluble fraction averages about 10 percent. Quartz, in the silt range, is characteristic of all the residues, but there is less organic matter in the eastern part of the facies.

X-ray diffraction. Analyses of several specimens indicate that much of the limestone is dolomitic (i.e., between 10 and 50 percent dolomite).

Contacts. The lower contact with the Rochester Shale is exposed along Sodus Creek west of Rose (loc. 119, Clyde quadrangle). There, the gradational contact is marked by an interval of interbedded, fossil-fragmental, crinoidal limestones and darker, thin-bedded, aphanitic limestone that is typical of the immediately overlying Lockport. So far as is known, there is no exposure of the Sconondoa-Vernon contact. In places, particularly in the eastern part of this area, the limestone is overlain and underlain by the dolomite facies. In the western part of the Clyde quadrangle, the limestone

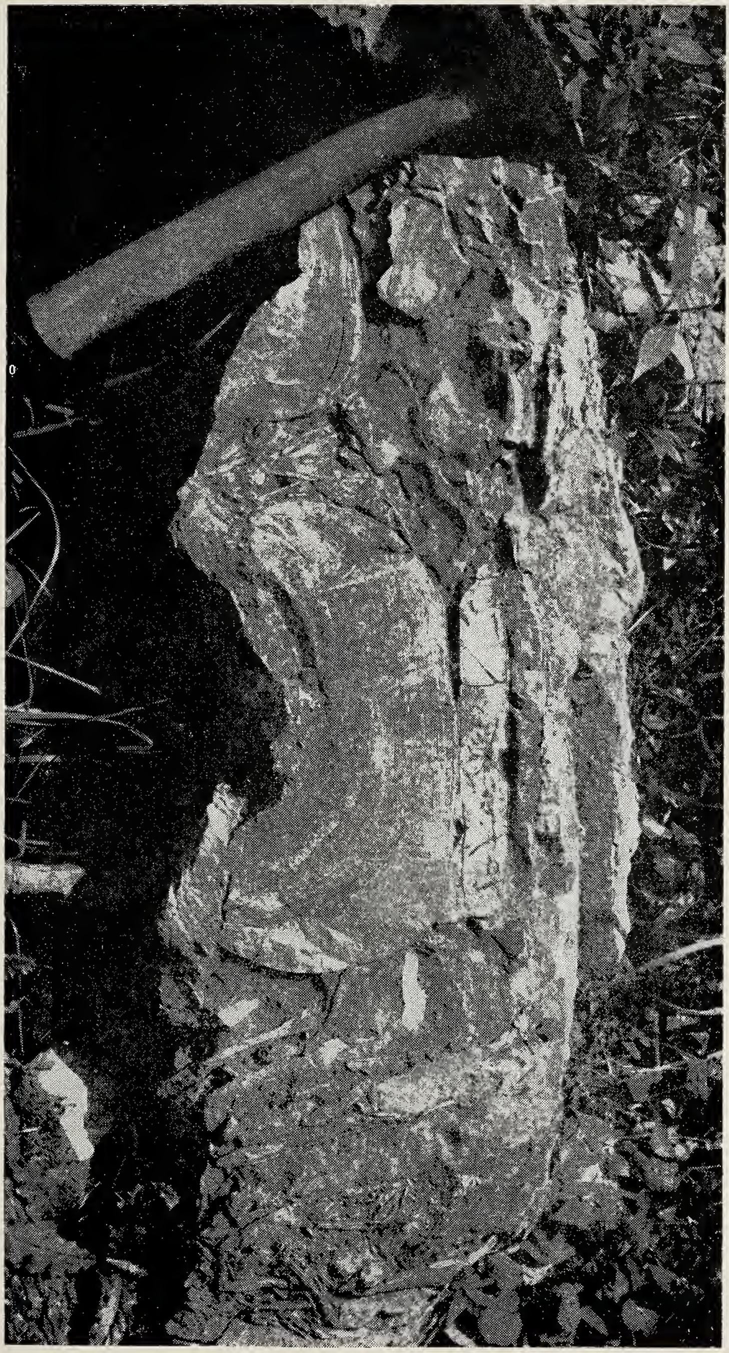

FIGURE 15. Stromatolite heads and associated edgewise conglomerates in limestone facies along Sconondoa Creek east of Vernon.

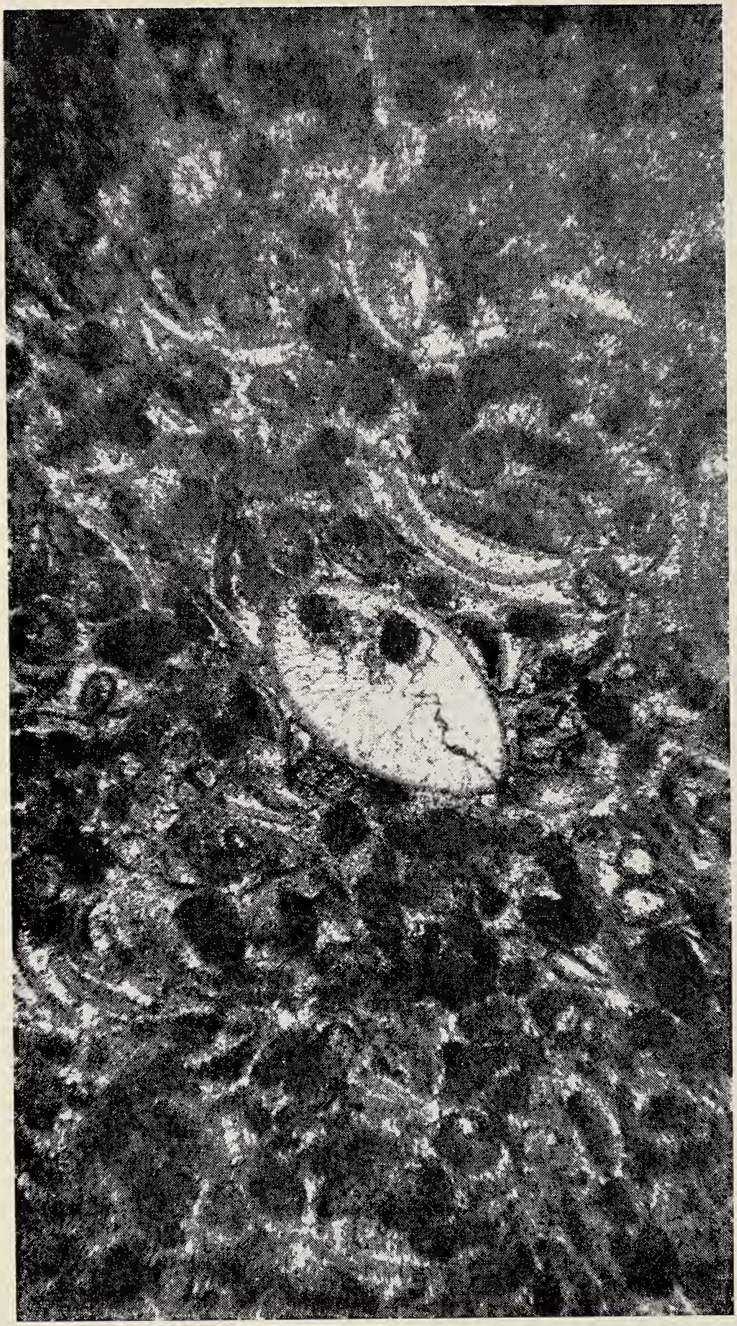

FIGURE 16. Photomicrograph. Ostracode *Eukloedenella* in pellet-rich specimen of limestone facies of Sconondoa Member. Note pellets in calcite filling of ostracode (plane polarized, X35).

facies is overlain by brown, medium-grained, bituminous dolomite that represents the easternmost exposure of the Oak Orchard Member.

Paleontology. Both facies of the Sconondoa Member contain a fossil assemblage in which the relative importance of the various groups differs noticeably from that in the outcrop belt to the west. Stromatoporoids are absent and *Favosites* is the sole coral present, except for *Cyathophyllum*? at loc. 118.[4] The most characteristic fossils, in addition to the stromatolites, are the brachiopod *Howellella,* the pelecypod *Pterinea,* and the leperditiid *Herrmannina.* Several genera of smaller ostracodes are present, including *Eukloedenella, Kloedenia,* and *Dizygopleura.* The total list of fossils in both facies of the Sconondoa is given in Table 5.

Comments. To the west, the limestone facies grades into the Oak Orchard and upper Penfield Members; to the east, it interfingers with the dolomite facies before both pass into the Ilion Member. Peculiar " markings " are found in both the limestone and dolomite facies. These consist of single, bifid, or trifid to subradiate ridges that presumably represent the fillings of cracks. The writer has seen cracks with similar patterns in the silt at the bottom of the Barge Canal when it is exposed during the winter months. They are regarded as incomplete mud cracks (see also Shrock, 1948, pp. 192–194).

Dolomite facies

Reference outcrops. Small exposures in the Syracuse, Chittenango, and Oneida quadrangles (locs. 140, 142, and 144, respectively) serve as reference " outcrops " for the dolomite facies.

Extent and thickness. The facies is exposed in the quadrangles just mentioned. Accurate thicknesses are not obtainable because of few and small outcrops and the complex interfingering with the limestone facies. The eastern margin of the dolomite facies is drawn arbitrarily at the eastern edge of the Oneida quadrangle, although there are dolomite beds intercalated with the Ilion shales in the Rome, Utica, and Winfield quadrangles.

Lithologic description. Superficially, the dolomite facies bears little resemblance to the limestone facies. The former consists predominantly of brownish-gray to grayish-black, medium-grained, thin- to medium-bedded, sparkling dolomite. On closer examination, however, the lithologies are seen to be similar. Laminations and cross laminations, shaly and shaly-bedded partings, incomplete mud cracks, intraformational conglomerates, ripple marks, ostracode-rich zones, and stomatolites with associated edgewise conglomerates are as common in the dolomite as in the limestone. Vugs containing minerals, however, were observed only in the dolomite facies.

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[4] Gilllette (1940, p. 101), however, reported *Halysites* and *Cladopora* from the Lockport (Sconondoa?) in the Clyde quadrangle.

Microscopic petrography. The dolomite consists of interlocking, equigranular, anhedral and subhedral grains averaging about 0.2 mm. in size. Of special interest are the ghosts of pellets, oolites, and ostracodes that have been almost obliterated by the dolomitization process. In most instances, these relict structures are distinguished by a darker shade of gray or brown. Some oolites have a vague concentric or radial structure. Dolomite grains transect the structures and fossils indiscriminantly. Shadowy rhombic outlines, surrounded by optically continuous dolomite, suggest that much of the present dolomite has grown through both rim cementation (Bathurst, 1959) and recrystallization. Quartz and pyrite are present in small amounts.

Insoluble residues. The dolomite facies in the Syracuse and Chittenango quadrangles is low in terrigenous material, averaging less than 4 percent insoluble. Impurities are higher in the eastern part of the Oneida quadrangle (loc. 154), where two samples averaged 15 percent insoluble. As was expected, the residues are composed of quartz, in the silt and sand range, and argillaceous matter.

X-ray diffraction. Little or no calcite occurs in the typical dolomite facies. If calcite is present in the analyzed samples, the amounts are so small that a calcite peak at $2\theta = 29.5°$ is not recorded.

Contacts. The conformable Rochester-dolomite facies contact is exposed at Canaseraga Creek (loc. 142) in the Chittenango quadrangle. There, the Rochester grades upward into the dolomite through a 2-foot transition zone of interlaminated dolomite and mudstone.

The lower contact with the Herkimer is exposed farther east along Sconondoa Creek (locs. 149 and 154), where the lowermost Sconondoa consists of an alternation of shale and dolomite. These shales represent the beginning of the eastward transition to the Ilion Member. The contact is set just above the uppermost crinoidal dolomite. An irregularly bedded, pyritic and hematitic, crinoidal stratum is present near the top of the Herkimer at Sconondoa Creek just east of Vernon (loc. 154). Conceivably, this bed represents a local condensation. However, because there are beds of Herkimerlike lithology in the lowermost Sconondoa at both of these localities (i.e., 149 and 154), it is believed that the contact is gradational. The upper contact with the Vernon is not exposed.

Paleontology. The fossils in the dolomite facies are the same as those in the limestone facies, but they are less well preserved. The predominant forms are *Howellella, Pterinea, Herrmannina, Eukloedenella,* and stromatolites. *Hormotoma* cf. *gregaria* was seen in both the lowermost Sconondoa and the uppermost Herkimer. Table 5 contains the list of Sconondoa fossils.

Comments. Most of the differences in the lithologies of the two facies are attributed to dolomitization. Since Vanuxem's efforts, little stratigraphic work has been done on the Lockport in this east-central area. Admittedly, the flat lake plain characterized by few outcrops is not an inspiring one in which to do field work. However, as will be elaborated later, careful study in this critical area shows that the Sconondoa Member connects the main mass of dolomite to the west with the Ilion Member to the east.

Table 5. Distribution of Sconondoa fossils
(L=limestone facies; D=dolomite facies)

Fossils	Localities												
	118 L	123 L	126 L	133 L	134 LD	135 D	138 D	140 D	148 L	149 D	151 L	153 LD	154 LD
Plantae?													
Stromatolites				X	XL	X					X	XL	X
Vermes													
Serpula? sp.*													
Anthozoa													
Cyathophyllum? sp.	X												
Enterolasma caliculum (Hall)	X												
Favosites niagarensis (Hall)		X											
F. sp. A	X												
F. sp. B	X	X								X			XL
F. sp.				X		X							
Brachiopoda													
Atrypa reticularis (Linnaeus)		X											
Coelospira? cf. *plicatula* (Hall)											X		
Howellella sp. A			X										
H. sp. B	X	X									X		
H. sp. C	X	X	X	X	X	X	X	X	X	X		XD	XL
Scenidium? *pyramidale* Hall				X									

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* Found only at loc. 122, limestone facies.

Table 5. Distribution of Sconondoa fossils (Concluded)
(L=limestone facies; D=dolomite facies)

Fossils	Localities												
	118	123	126	133	134	135	138	140	148	149	151	153	154
	L	L	L	L	LD	D	D	D	L	D	L	LD	LD
Pelecypoda													
Pterinea sp.			X		XD			X					
Gastropoda													
Hormotoma cf. *gregaria* Ruedemann													X
Cephalopoda													
Protokionoceras? *trusitum* (Clarke and Ruedemann)	X												
Eurypterida													
Eusarcus sp.	X												
Ostracoda**													
Dizygopleura sp. aff. *D. swartzi* Ulrich and Bassler				X								XL	
Eukloedenella sp. aff. *E. indivisa* Ulrich and Bassler		X		X								XL	
E. sp. aff. *E. sinuata* Ulrich and Bassler				X								XL	
E. sp.					XD			X					
Herrmannina sp.		X		X	XD		X	X				XL	
Herrmannina? sp.	X												
Kloedenia? sp.	X												
Mirochilina sp.	X												

** Most identifications of ostracodes by Dr. Jean M. Berdan.

STRATIGRAPHY OF THE EASTERN AREA
(Rome, Utica, and Winfield quadrangles)

GENERAL

The relief in this area is much greater than elsewhere along the outcrop belt. Streams flowing over the north-facing escarpment into the Mohawk Valley Lowland cut through the Upper Ordovician, Silurian, and Lower Devonian sequence. Consequently, there are many good sections of most of the units, particularly of the shale that occupies the stratigraphic position of the Lockport limestone and dolomite members to the west.

ILION MEMBER

Name and type section. The nearly continuous sequence of shale and dolomite along Starch Factory Creek (Utica quadrangle, loc. 165 of this report), southwest of Ilion, was designated the type section of the Ilion Shale (Fisher, 1960).

Extent and thickness. The Ilion Member comprises the entire Lockport sequence in the Rome, Utica, and Winfield quadrangles. Figure 17 is a columnar section of the Ilion in the Rome quadrangle. The western margin of the Rome quadrangle is chosen arbitrarily as the western limit of the Ilion, but, as previously mentioned, there is considerable shale intercalated with the Sconondoa Member in the Oneida quadrangle (see figure 18). The easternmost exposure of the Ilion lithology is along Steele Creek (locs. 168–172) in the Winfield quadrangle. At Clinton (Rome quadrangle) the Ilion is about 70 feet thick, but it thins to 40 feet south of Utica and to 20 feet at Steele Creek.

Lithologic description. The main mass of the Ilion consists of shale and mudstone, which range from greenish gray to grayish black. The splitting is chippy, platy, fissile, or paper thin. The fissile and paper-thin varieties are commonly soft clay shales, whereas the platy and chippy shales are harder. Thin zones of brownish-yellow,

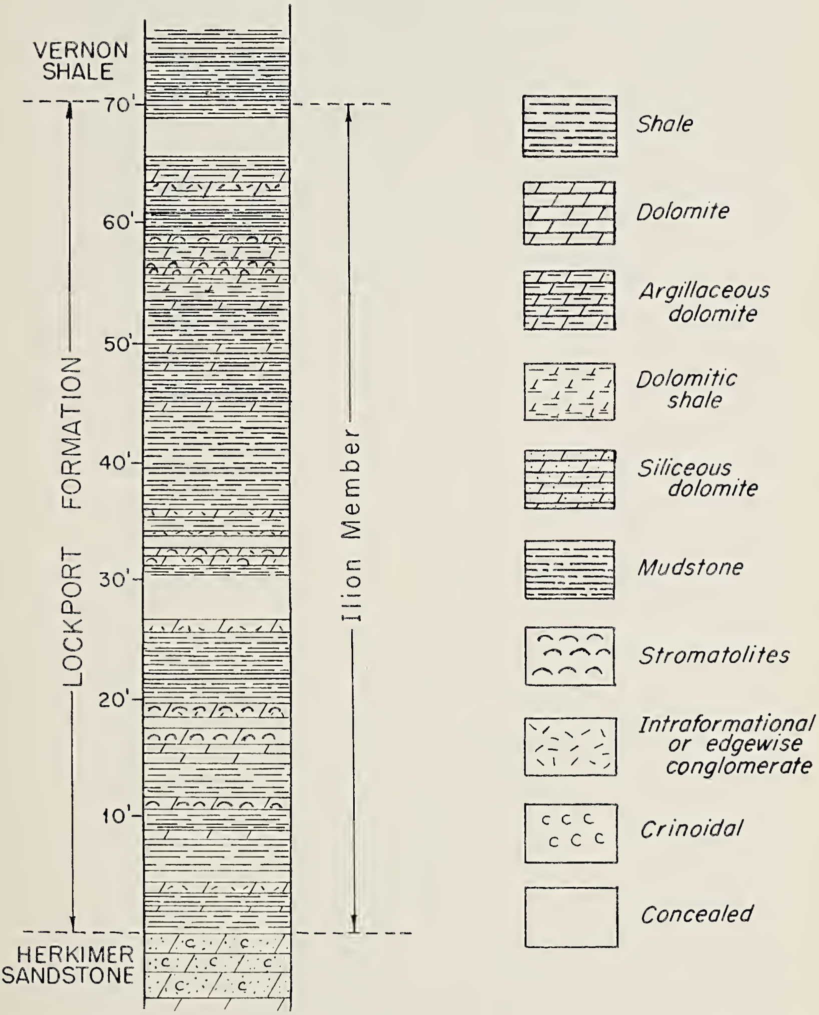

FIGURE 17. Columnar section of Ilion Member near Clinton in Rome quadrangle.

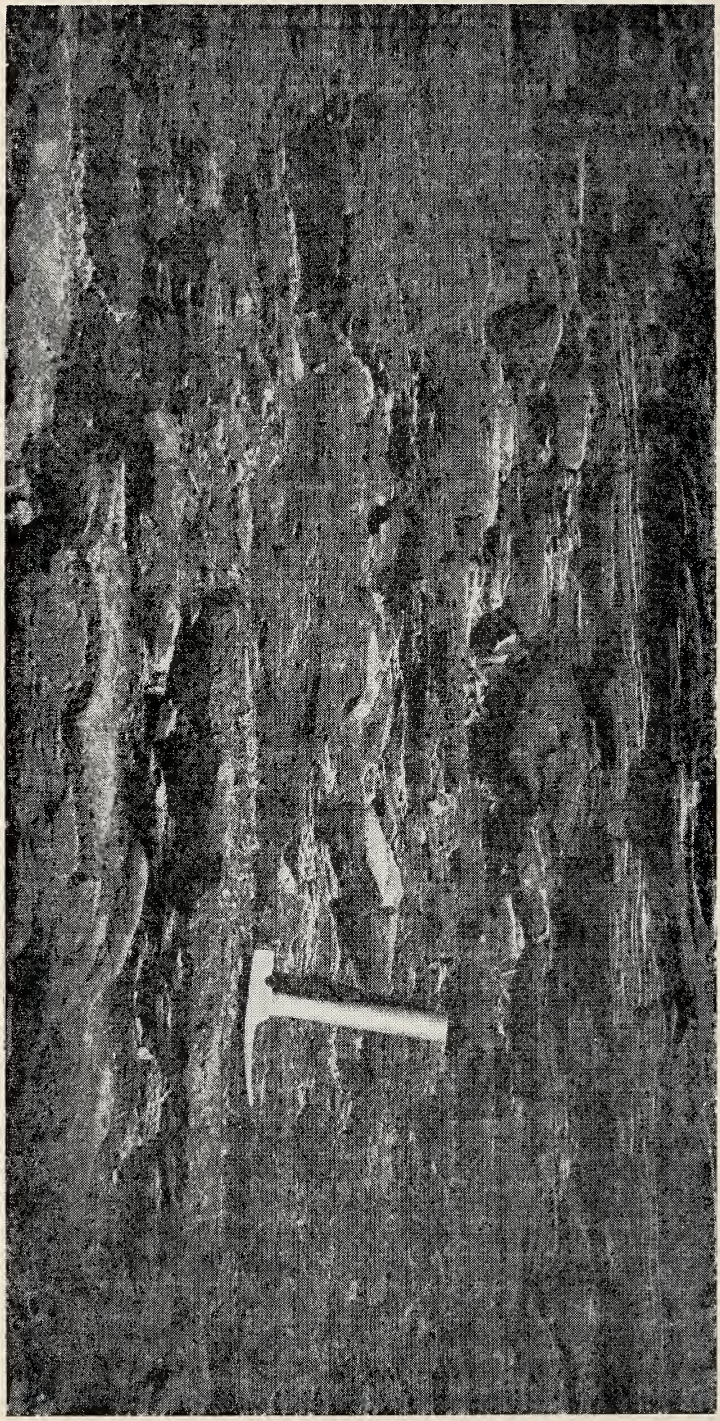

FIGURE 18. Interfingering of Ilion Shale and stromatolitic limestone of Sconondoa Member along Sconondoa Creek at Sherrill.

iron-stained shales and thin clay seams were observed. The lumpy mudstones generally are dark gray and very fine grained and characteristically show no fissility. Some mudstones are more indurated. The lower and upper parts of the Ilion are predominantly argillaceous, although there are sporadic, thin, intercalated dolomite beds. Dolomite beds in the Ilion are dark gray, fine to medium grained, sparkling and argillaceous. With the exception of the section at Lairdsville (loc. 156, unit 4), no dolomite sequence is more than 2 feet thick. Many of the dolomite beds are stromatolitic and consist of hemispherical domes. These irregular beds were called " stromatoporoid reefs " by Dale (1953, pp. 103–106), but his mention of algal reefs suggests that he had the correct view. Grossman (1953, p. 70), on the other hand, believed that these beds were the result of solution phenomena. Preservation of the stromatolites is poor, but the presence of the domal shape, nodose surfaces, and laminations indicate that these structures are the same as those in the carbonates to the west. Edgewise conglomerates invariably are associated with the stromatolites. Intraformational conglomerates in some of the nonstromatolitic dolomites contain intraclasts that have their longest dimension parallel to the bedding. In the Utica and Winfield quadrangles, the dolomite is less pure, and is both argillaceous and siliceous. A greenish-gray sandstone bed, resembling the underlying Herkimer Sandstone, is exposed about 7 feet above the base of the Ilion at South Moyer Creek (loc. 166, Utica quadrangle). Two thin quartzite layers of definite Herkimer affinity are interbedded with the shale in the Ilion Gorge (Winfield quadrangle, loc. 169). The stromatolite beds are commonly vuggy; the voids contain dolomite, calcite, quartz, and sphalerite. Pyrite and chalcopyrite are abundant in the member.

Microscopic petrography. Several specimens of the stromatolites and intraformational conglomerates were studied in thin section. The stromatolitic dolomite consists of subinterlocking anhedral and subhedral dolomite grains that range in size from .02 to 0.1 mm. The matrix is a microcrystalline dolomite containing some argillaceous and organic matter. Many of the dolomite grains are corroded by this matrix and are not in contact. Clear areas represent secondarily precipitated dolomite. Disseminated pyrite and scattered detrital quartz grains are present in the sections. More detail on the stromatolite structures is presented in the section on Stromatolites. One specimen of an intraformational conglomerate shows the intraclasts embedded in a groundmass of interlocking subhedral and anhedral dolomite grains. These rounded, elongate intraclasts are as much as 15 mm. long. Their grain size is less than that of the groundmass. The groundmass-intraclast contacts may be sharply defined or hazy.

In the latter case, the boundaries commonly are marked by a dark, organic rind. The section shows relicts of small ostracodes. Some fossil fragments are heavily pyritized. Quartz grains are present both in the intraclasts and in the matrix. Another specimen, from the uppermost bed of intraformational conglomerate just south of College Hill (loc. 157, unit 6) in the Rome quadrangle, is much the same as the preceding section. Here the intraclasts are smaller and consist of very fine-grained to microcrystalline dolomite. Ghosts of pellets and oolites(?) were seen in the matrix.

Insoluble residues. The intercalated dolomite beds in the Ilion Member are more highly insoluble than the carbonates in the Sconondoa. The range of insoluble content is from 5.2 to 28.2 percent. The sandstone bed at South Moyer Creek (loc. 166) is over 90 percent insoluble. Most of the shales are nondolomitic. Because there is considerably more shale than dolomite in the Ilion, we may conclude that the unit is composed largely of terrigenous matter. The residues are olive-gray to brownish-gray mixtures of clay- and silt-sized quartz.

X-ray diffraction. The chief carbonate mineral in the Ilion is dolomite. The study also shows that much of what is taken to be " argillaceous " in the field actually is very fine quartz.

Contacts. Gillette (1947, pp. 107, 113), on the basis of a ". . . decided undulating and truncated upper surface of the Herkimer in Oneida County " placed a " marked unconformity " between the Herkimer and Ilion. Dale's remarks (1953, pp. 104, 108) are not completely clear. He first mentioned that at Farmers Mills (loc. 159 of this report) the Ilion meets ". . . the overlying Vernon by a sharp contact." Thereafter, however (p. 108), with reference to the Vernon Shale, he commented that " no contacts with the overlying Camillus or underlying Lockport are known in the area . . ." It is interesting to note that Alling (1928, pp. 31–32) also observed the contact at Farmers Mills and believed it to be ". . . gradational with no sign of erosion prior to deposition of the Vernon."

Grossman (1953, p. 71) apparently considered the Herkimer-Lockport contact in the Utica quadrangle to be conformable, and he wrote of the upper contact:

> " In the only locality where the contact with the basal green shale of the Vernon was seen, the tributary of Starch Factory Creek, the blue-gray shale of the Lockport seems to grade into the overlying formation. Inasmuch as there is considerable disconformity between the attenuated Lockport and the Vernon

> west of the area, the dark shales may be a basal part of the Cayugan Series."

Fisher (1960) showed disconformities above and below the Ilion. The Herkimer Sandstone, which underlies the Ilion, is an extremely variable sequence of sandstones, siltstones, silty and sandy shales, and dolomite. Phosphatic and hematitic beds, clay galls, and zones of intraformational conglomerates are characteristic of the unit. Pararipples, some of which have wave lengths of more than 3 feet, are fairly common. The uppermost part of the Herkimer in the Rome and Utica quadrangles consist of crinoidal dolomites and shales. In the eastern part of the Winfield quadrangle and the adjoining Richfield Springs quadrangle on the east, the Herkimer is light-gray orthoquartzite.

The nature of the Herkimer-Ilion contact was studied at several places (locs. 158, 164, 165, 166, and 169). The writer feels that conclusive evidence of an unconformity is lacking. The undulating surface referred to by Gillette (1947, pp. 107, 113) apparently is due to large ripple marks. In fact, there is good evidence not only for a gradational contact but also an interfingering one. The contact, in most instances difficult to establish exactly, is placed arbitrarily at the top of the uppermost crinoidal dolomite. Commonly these dolomites contain tentaculitids and high-spired gastropods (*Hormotoma*). The difficulty in placing the contact is increased, due to the presence of similar dolomitic shales in both the upper Herkimer and the lower Ilion. In addition, Herkimerlike dolomite beds occur in the lower few feet of the Ilion. These dolomites are somewhat lighter and less " sparkling " than those typical of the Ilion. Paleontological criteria were useful in establishing this contact. The lower shales of the Ilion contain *Howellella* and *Pterinea*. The Herkimerlike dolomite beds contain *Favosites*. These faunal elements belong to the Lockport, as they have been traced into the Ilion from the western carbonates. The lowermost Vernon Shale is a greenish to greenish-gray mudstone and shale about 7 feet thick. The typical red Vernon is above this lower unit. There seems to be no evidence of an Ilion-Vernon disconformity west of the Ilion Gorge. The contact, which is exposed at several places (locs. 159, 163, 164, 165, 166, 169, and 170), is gradational to interfigering. The uppermost Ilion has interlaminations of the typical grayish-black shale and the grayish-green Vernon. This transition zone is commonly about a foot thick. Just east of Sauquoit, on the western margin of the Utica quadrangle (loc. 164), a dark-gray stromatolite bed occurs within the basal green Vernon. There is a peculiar transition zone between the Ilion and the Vernon in the Ilion Gorge. Overlying the uppermost stromatolite domes in the Ilion is a thin sequence of greenish-gray shales containing small, black nodules (chamosite?). These are followed by a 5-inch bed of dense, pyritic, and hematitic dolomite. Lingulids, similar to those in the Ilion farther west, are present in the greenish shales of the typical Vernon that overlie this mineralized bed.

The Ilion lithology is missing east of the Ilion Gorge. At Spinnerville Gulf (loc. 173) and Flat Creek (loc. 174), in the Richfield Springs quadrangle, the uppermost quartzite of the Herkimer is limonitic and friable. Digging was necessary in order to make a very localized examination of the lithology above the Herkimer. The observed greenish-yellow shale and mudstone are assigned to the Vernon. A few miles to the east, just south of Deck, the Vernon also is absent and the Brayman Shale unconformably overlies the Herkimer. At this place (loc. 175), the uppermost Herkimer beneath the undulating contact is limonitic and friable. This is overlain by a thin clay bed containing rounded quartz pebbles that undoubtedly represents erosion during post-Herkimer and pre-Brayman time.

Paleontology. Generally, fossils are rare in the Ilion, lingulids and stromatolites being the most abundant of those forms that are present. So far as is known, only the following have been reported prior to this investigation: *Lingula vicina, Orbiculoidea molina, Carcinosoma vaningeni,* stromatoporoids, and " seaweed " (Ruedemann, 1916, p. 69; Dale, 1953, p. 105; Leutze, 1959, pp. 42–43; and Fisher, 1960). Assuming that " stromatoporoids " refer to the stromatolites of this report, the writer has collected or seen all the above with the possible exception of *Carcinosoma.* This eurypterid was not found at Farmers Mills, where it had been reported (Ruedemann, 1916, p. 69), but telsons and scalelike markings at other localities belong to an unidentifiable eurypterid, possibly *Carcinosoma.*

Lingulids are present throughout the member; they are very profuse in some layers. Most of the specimens collected by the writer resemble Ruedemann's (1916) *Lingula semina* from the Pittsford, rather than his *L. vicina* from the Ilion. The " seaweed " mentioned by Dale (1953, p. 105) was seen by this writer at both Farmers Mills (loc. 159) and south of College Hill (loc. 157) in the Rome quadrangle.

In addition to these fossils, the writer has found a fauna previously unreported from the Ilion. This fauna is small and sparse; in fact, the best collecting is from a thin zone (locs. 158, 166) in the lower part of the member. Three of the genera, *Howellella, Pterinea,* and *Herrmannina* are significant; they have been traced across the carbonate belt and into the Ilion. *Howellella* and *Pterinea* are associated in the lower part, with the exception of the section at Lairdsville, where they occur in the middle of the unit. The leperditiid *Herrmannina* is abundant in certain layers at Steele Creek (locs. 169 and 170). A complete list of Ilion fossils is presented in Table 6.

Comments. The sandstones and quartzites intercalated in the shales seem to be indisputable proof that at least a part of the Ilion grades eastward to the Herkimer. The Ilion Member differs from other units of the Lockport Formation primarily in the abundance of shale. This, and the presence of *Carcinosoma* and *Lingula,* has led some to correlate part of the interval with the Pittsford Shale (Hartnagel, 1907, p. 29; Clarke and Ruedemann, 1912, p. 421; Grossman, 1953, p. 71). The locality along the Barge Canal, where the Pittsford was originally described (Sarle, 1902, p. 1,082), is no longer in existence. The writer visited the area during the winter of 1962, when the water was drained from the canal. Blocks of Lockport and Grimsby Sandstone have been dumped along the side, concealing any exposure that was there. A comparison of the lithology and lingulids of the Ilion with those of the Pittsford, from the New York State Museum, reveals a striking similarity. The Pittsford, however, is believed to be only a local facies of the Vernon (Leutze, 1959, p. 33; Fisher, 1960). This writer believes that the blackish shales of the Ilion and Pittsford, although not necessarily correlatives, certainly represent similar lithotopes.

Table 6. Distribution of Ilion fossils

Fossils	Localities							
	154*	156	157	158	164	166	169	170
Plantae?								
Stromatolites	X	X	X	X	X	X	X	X
" Seaweed "		X	X					
Vermes								
Spirorbis sp.								X
Anthozoa								
Favosites sp. A		X		X		X		
F. sp. B							X	
Conularida								
Conularia sp.				X				
Bryozoa								
Bryozoa indet.						X		
Brachiopoda								
Howellella sp. A						X	X	
H. sp. B	X							
H. sp. C	X		X	X	X	X	X	
Lingula semina Ruedemann	X			X		X	X	
L. vicina Ruedemann			X		X			
Orbiculoidea molina Ruedemann				X				
Homeospira? spp.	X			X		X	X	
Scenidium? *pyramidale* (Hall)	X			X				

Table 6. Distribution of Ilion fossils (Concluded)

Fossils	Localities							
	154*	156	157	158	164	166	169	170
Pelecypoda								
Leiopteria subplana? (Hall)	X							
Pterinea sp.		X		X		X		
Pyrenomoeus cuneatus (Hall)	X			X				
Eurypterida								
Eurypterida indet.	X					X		
Ostracoda								
Dizygopleura sp. aff. *D. swartzi* Ulrich and Bassler	X	X				X		
Herrmannina sp.							X	X
Conodontophoridia								
Conodontophoridia sp.						X		

* Shale intercalated in Sconondoa Member along Sconondoa Creek east of Vernon.

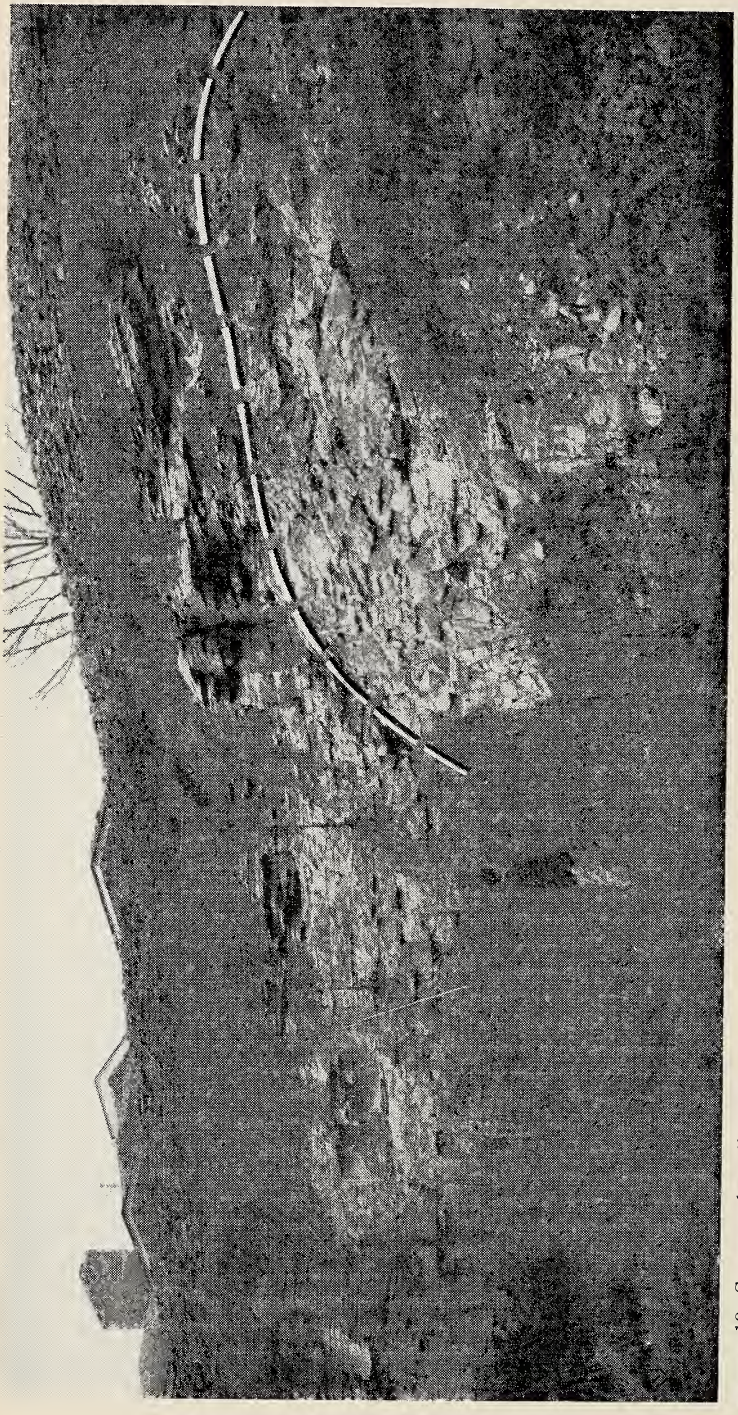

FIGURE 19. Structureless limestone bioherm in Gasport Member 2 miles west of Lockport; note bedded Gasport to left of, and above, bioherm.

Special Features

BIOHERMS AND BIOSTROMES

" Reef " limestones and dolomites, excluding stromatolitic masses, are in the form of tabular bodies (biostromes) or moundlike structures (bioherms). The term " reef " implies more than is suggested by these Lockport bodies and is not used for them. Bioherms in the Lockport are restricted to the Gasport Member. They constitute the eastward extension of an area of greater reef development in Indiana, Illinois, and Wisconsin (Lowenstam, 1950 and 1957; Cumings and Shrock, 1928). Gasport bioherms were observed on both sides of the Niagara Gorge, at Pekin (loc. 14), west and southwest of Lockport (locs. 24, 28, 29; figure 19), at Gasport (loc. 37; see figures 20, 21), and at Clarendon (loc. 57). The writer did not see any of these structures east of the Albion quadrangle, although some limited surface exposures in the Bergen quadrangle resemble the biohermal type of lithology. Gillette (1940, pp. 98–101) reported coral " reefs " in the Clyde quadrangle. Those seen by this writer appear to be biostromes, but the outcrops are too small to permit a conclusive statement.

Whereas many of the Silurian reefs reported by Cumings and Shrock (1928), Hadding (1941), and Lowenstam (1950, 1957) have a lateral extent of from several hundred feet to more than a mile, the Lockport bioherms are generally less than 100 feet across. Cumings and Shrock (p. 603) described reefs in Indiana having a height of 70 to 80 feet. Hadding (p. 13) reported a range of from 1 to 30 meters for the vertical extent of the Gotland reefs. Lowenstam stated that reefs in Illinois range in height from a few feet to over 1,000 feet. The bioherms in the Lockport may attain a height of 30 feet, but generally are less. It was observed that the east-west extent is commonly greater than that along a north-south line. Most of the bioherms have steep sides.

As in Indiana (Cumings and Shrock, 1928), most of the Lockport bioherms have been dolomitized. The limestone bioherms in the Gasport contain a profuse and nearly exclusive coral and stromatoporoid fauna. Some of the fossils in the limestone bioherms are well preserved, but in others recrystallization has obscured the internal struc-

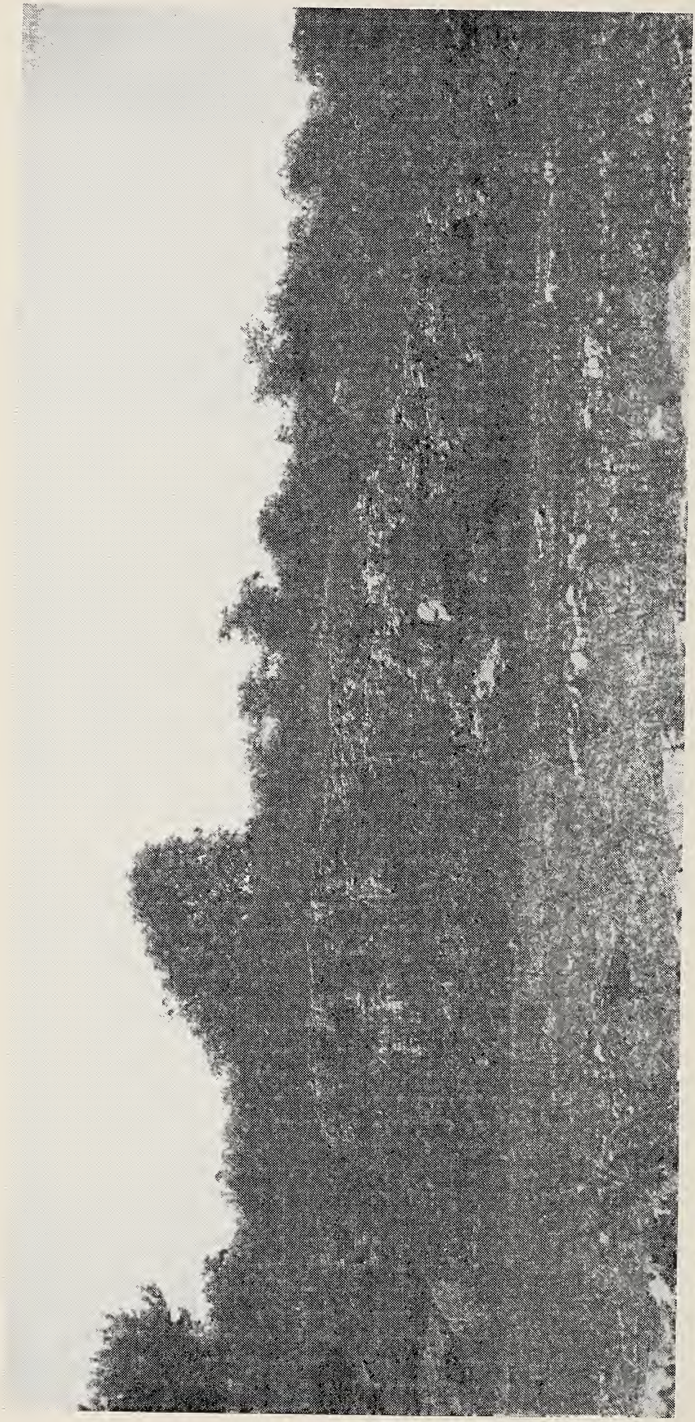

FIGURE 20. Lens-shaped, dolomitized bioherm in Gasport Member at Royalton quarry, Gasport; the bioherm is about 45 feet across.

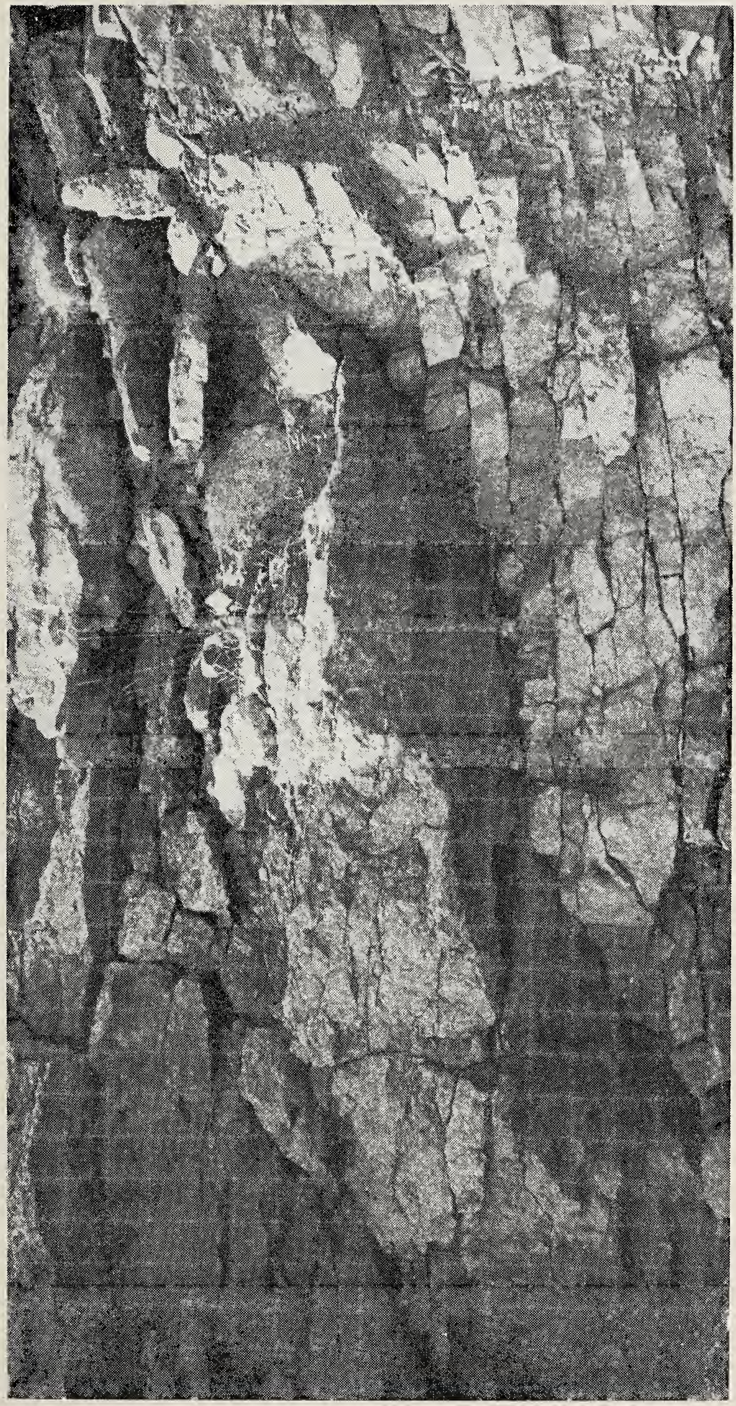

FIGURE 21. Close-up of western margin of bioherm in figure 20 showing sharp contact with distinctly bedded, crinoidal Gasport.

tural detail. In the dolomitized bioherms, however, the state of preservation is so poor that one is forced to make a careful examination in order to verify the very existence of fossils. Corals and stromatoporoids were also the dominant Niagaran reef builders in Illinois and Indiana. Hadding (1941, p. 14) listed these coelenterates, together with bryozoans and calcareous algae, as the important framework organisms in the Gotland reefs. The bioherms consist of light-gray, very fine-grained, massive, compact, structureless limestone or dolomite. In cross section, the shape varies from elliptical to mound-shaped. Very gently dipping flank beds, consisting of coral and stromatoporoid debris, are present on the margins of some of the structures. Cumings and Shrock (1928) reported many Indiana reefs having well-displayed, steeply dipping flank beds. Lowenstam (1957, pp. 225–227) mentioned that in the clastic-free zone of the subsurface Niagaran in Illinois, increased turbulence prevented the development of flank beds because the debris was carried into the interreef areas. This may have been the case with the Lockport bioherms lacking flank beds.

An apparent anomaly is that insoluble residues are higher in the Gasport bioherms and flank beds than in the surrounding crinoidal layers. Generally, reefs and bioherms are low in terrigenous clastics because reef builders have a low mud tolerance. In this case, the bioherms must have acted as a sediment trap for this terrigenous material that elsewhere was transported farther offshore. This influx of mud and silt might have acted as a deterrent to growth of the small bioherms.

Biostromes also occur in the Gasport, but extend higher stratigraphically and farther east. Stromatoporoid biostromes are the most common type and are well exposed in the quarries at Lockport and Gasport (locs. 29 and 37 respectively). Two Oak Orchard biostromes, composed of a profusion of poorly preserved stromatoporoids and the corals *Halysites* and *Cladopora,* occur in the upper part of the Penfield quarry (loc. 92) just east of Rochester. Many of the stromatoporoids are not in growth position; their various orientations may result from settling in the substrate. *Favosites* biostromes are most common in the Oak Orchard Member. Two examples can be seen in the Niagara Stone quarry (loc. 9) east of Niagara Falls and in the General Crushed Stone quarry (loc. 117), south of Sodus.

STROMATOLITES

Stromatolites are among the more interesting structures in the Lockport Formation. Hall (1843, pp. 93–95) and Vanuxem (1842, pp. 90–93) noticed and described concretionary structures in the Lockport. Kindle and Taylor (1913, Pl. 24) illustrated " curved plates " in the upper part of the Lockport at Niagara Falls. Dale (1953, p. 103) mentioned " algal reefs " in his introductory remarks regarding the Lockport in the Rome quadrangle, but subsequently he referred to the same structures as " stromatoporoid reefs." Stromatolites are present in the upper part of the Lockport, or Oak Orchard Member, between Niagara Falls and the Clyde quadrangle. East of Clyde, they appear lower, relative to the base of the Lockport, and at Syracuse and eastward, they were observed throughout the sequence.

The external forms vary within limits. In the Oak Orchard Member at Niagara Falls, the massive stromatolites in the lower zone are from 4 feet to more than 10 feet across. The tops are convex upward, and the bases are less convex downward. The surfaces are smooth, ripple marked, or nodular. Thinner-bedded dolomite arches over and bends under the masses. The upper stromatolites in the Oak Orchard at Niagara (loc. 7) and south of Lockport (loc. 25) consist of hemispherical forms consisting of thin- to medium-bedded, laminated dolomite (see figure 22). The surfaces are nodose or ripple marked. Oolites, intraformational conglomerates, and ostracodes are associated with the stromatolites at both occurrances. Oak Orchard stromatolites at Rochester (loc. 90) consist of both the massive type and the arched, thinner-bedded layers. Intraformational and edgewise conglomerates are associated with the structures. Immediately to the east, in the Macedon quadrangle (loc. 102), the stromatolites are present either as laminated, slightly curved plates with nodose upper surfaces, or as separate heads 7–8 inches in diameter that are bound by nonstromatolitic dolomite. Platy, oolitic beds also are present.

These structures in the Sconondoa Member consist of hemispherical forms, the upper surfaces of which are characterized by either closely spaced protuberances or larger, mammillary prominences. The latter represent the heads of intimately associated colonies. Stromatolitic layers are especially well displayed at the type section of the Sconondoa Member (loc. 154; see figure 23). The beds com-

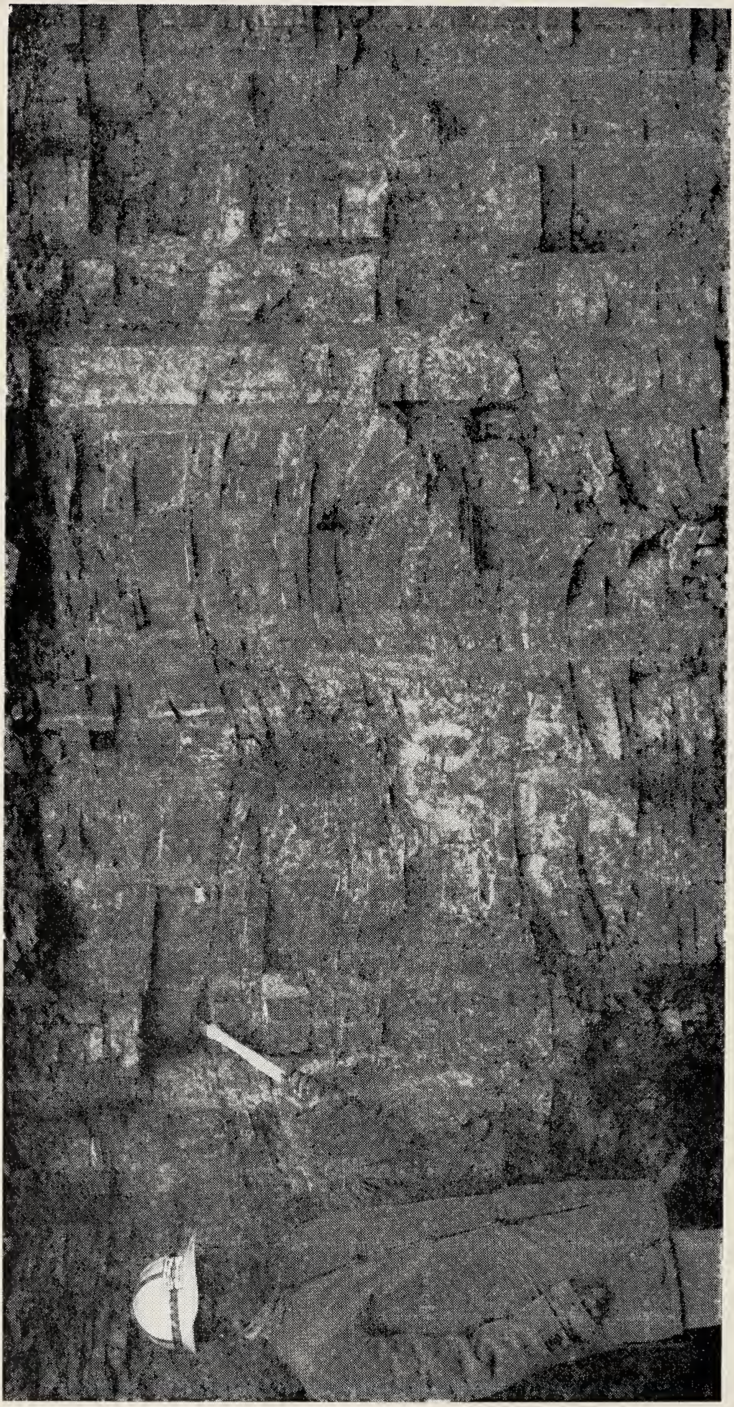

FIGURE 22. Upper zone of stromatolites in Oak Orchard Member at Niagara Falls.

monly are less than a foot thick; they are separated by nonstromatolitic sequences. It is possible that some may be biostromal in nature but, owing to lack of continuous exposures of any one bed, it is advisable to consider them simply as beds or masses. Edgewise conglomerates, the intraclasts of which are fragments of the "algal" limestone, occur in the downfolds between the domes.

The form of the stromatolites in the Ilion Member is much the same as elsewhere. They are hemispherical domes rarely more than 18 inches thick. Commonly, the upper surfaces are covered with wartlike bumps. Edgewise conglomerates are abundant. Stromatolites at two horizons at the College Hill section (loc. 158) are elongate in a N80°W orientation. Dolomitization, particularly in the Ilion Member, has destroyed much of the internal structure. In the field, cross sections of the structures show undulating, closely-spaced laminations that form convex upward arches 1 to 3 inches across. Vertical elements perpendicular to the laminae and the surface of the domes are common, and are aligned with the downbent margins of the small arches. Concentric laminations were observed in natural transverse sections (see figure 24F).

Dunbar and Rodgers (1957, p. 229) described stromatolites as follows:

> "They appear to form on and over colonies of blue-green algae (and to some extent green algae).[5] The mucilaginous jelly around the cells of the blue-green algae catches whatever lime mud drifts by, forming a layer of $CaCO_3$ (in addition some $CaCO_3$ may be precipitated as the algae withdraw CO_2 from the sea water in photosynthesis, stiffening the layer); the algae then grow out over the surface of the newly deposited layer, and the process is repeated. The result is a deposit of laminated but otherwise structureless $CaCO_3$ recording the successive growth of the algae. The laminae may be flat but more commonly they are humped up, forming bun-shaped heads of varying sizes or long parallel fingers."

A vertical thin section of a stromatolitic dome from the Niagara Stone quarry (loc. 9) consists of laminated dolomite in which the laminations are convex upward. Alternate laminae are 0.15 to 1.5 mm. thick and have a grain size up to 0.2 mm. The interlaminations are darker, thinner, and finer grained. The section includes one of

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[5] Fenton and Fenton (1958, p. 49), however, suggest the possibility that the ancient stromatolites may have been formed by red algae rather than by the blue-green type.

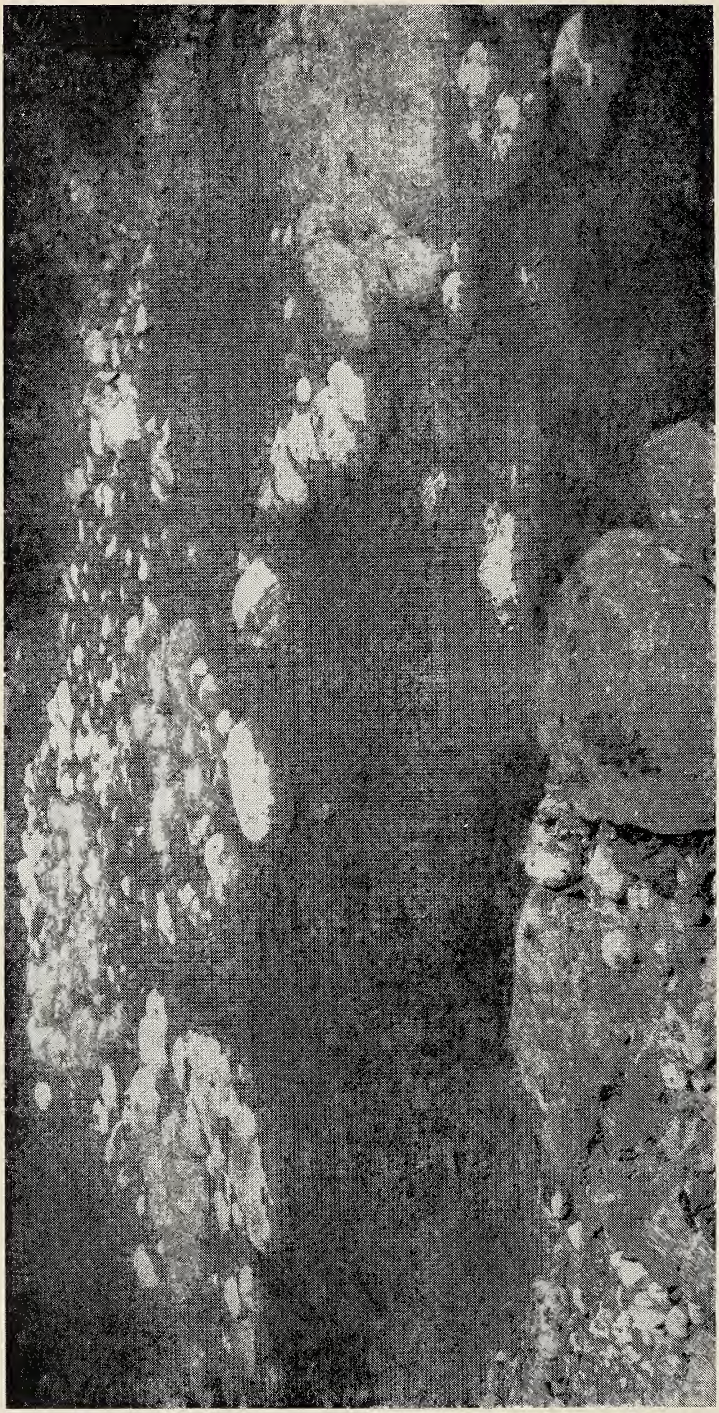
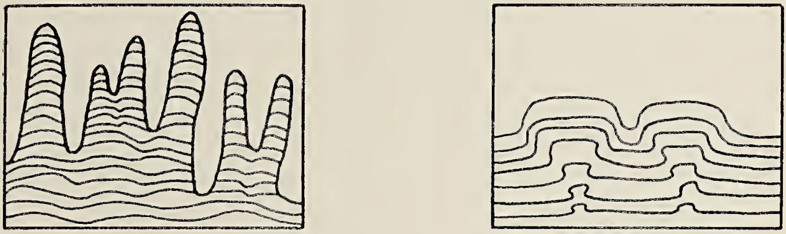


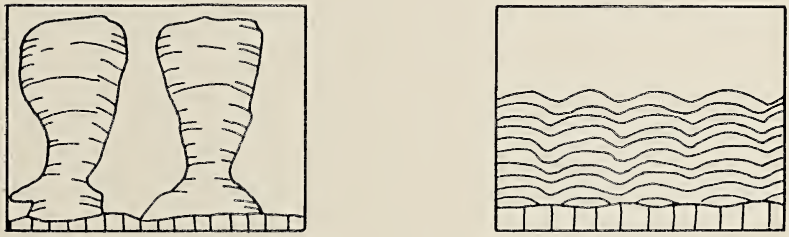
FIGURE 23. Small hemispherical domes in limestone facies of Sconondoa Member along Sconondoa Creek east of Vernon. Relative to stromatolites, Silurian sea level may have been approximately at position of present creek level.

the vertical elements previously mentioned. The dolomite in this structure is fine grained, much like that in the darker laminations. The laminations do not pass through these vertical elements, but either are bent down or end abruptly at their margins (see figure 24E).



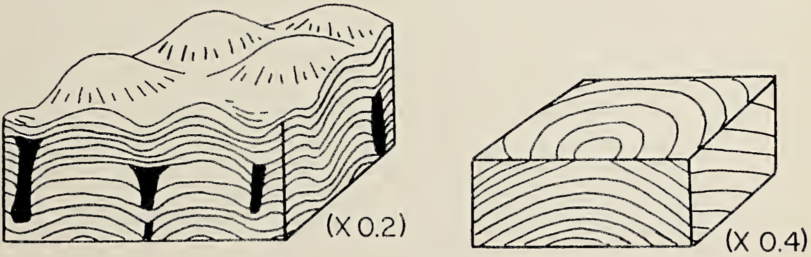
A. Gymnosolen (greatly reduced)

B. Cryptozoön (X 0.02)



C. Collenia (X 0.2)

D. Tabular stromatolite (X 0.02)



E. Block diagram of Lockport stromatolite; note laminations, mammillary upper surface, and vertical "fillings".

F. Block diagram of sectioned stromatolite; note concentric arrangement of laminations on horizontal section.

FIGURE 24. Stromatolitic forms and structures (A,C,D after Shrock, 1948, p. 287; B after Dunbar and Rodgers, 1957, p. 230)

A transverse section reveals that these vertical structures are tabular rather than tubular. It is unlikely, therefore, that they are part of the organic structure. They probably represent a filling of cracks between the arches, or an " injection " of carbonate mud into the downfolded portions prior to the solidification of the mass. In this specimen, then, the " growth laminations " are the only preserved structures that may reflect an organic, or partially organic, formation. A thin section of a stromatolite from an undolomitized bed in the Sconondoa Member, however, shows other interesting structures. Between and perpendicular to the laminations are zones containing numerous subparallel " threads " from 0.1 to 0.2 mm. in diameter. Although many of these " threads " branch upward, others bifucate downward. They are filled with very fine, clear calcite. The writer considers the possibility that these " threads " are fillings of former algal filaments. This problem was discussed with Dr. J. M. Kingsbury, Botany Department, Cornell University. Dr. Kingsbury did not deny the possibility that these might represent algal filaments, but he pointed out that they are larger and more orientated than filaments in recent algae. Another thin section of a stromatolite in the Ilion shows less well-preserved " threads." If not organic, these may be fillings of small desiccation cracks.

Although there are some dissenters, the consensus is that stromatolites have an organic origin. Cloud (1942, pp. 363–366) concluded that these ". . . laminated but otherwise structureless objects . . ." were found through the precipitation of $CaCO_3$ about the thalli of the algae, and consequently they are not actually part of the algal body. For this reason, and because stromatolites are believed to have been formed by assemblages of genera, Cloud felt that they should not be given specific names. He asserted that, owing to the lack of internal structures, names naturally would be based on external shape, which is a reflection more of ecology than of taxonomy. Cloud recommended the use of " form genera," such as cryptozoön, collenia, and gymnosolen (see figure 24).

Edgewise conglomerates, oolites, and ostracodes have been reported in association with other occurrences of stromatolites and algae. Goldring (1938) described *Cryptozoön* reefs from the Upper Cambrian of New York. Oolites (pp. 21, 23) and edgewise conglomerates (p. 17) accompany the algae.

Bradley (1929), in a study of freshwater algal reefs in the Green River Formation, cited several occurrences of oolites and edgewise conglomerates, the intraclasts of which rest ". . . in sharp downfolds of the algal colonies; evidently the investing medium of the algal cells was tough enough to bend sharply without breaking " (p. 213).

Many of his descriptions and illustrations resemble the stromatolites in the Lockport. Some, however, merit generic and specific names because algal cells and filaments are preserved. Bradley recognized others simply as pseudomorphs of the original algal colonies.

Recently, Logan (1961) has described cryptozoön and other stromatolites that presently are forming in Australia. There, the various kinds of cryptozoön stromatolites, such as flat, algal-laminated sediment, domed structures, and discrete club-shaped structures, are forming beneath active blue-green algal mats. Sediments deposited on the surfaces of the algal mats are bound into the structures by algal filaments. Descriptive terms used by Logan, such as "domed structures," hemispherical shells," and " undulose laminations," are familiar to the student of ancient stromatolites. The physical analogy between Logan's stromatolites and those in the Lockport is striking. In fact, here is an unusual opportunity to relate a recent organic sedimentation process to one of the oldest recorded organic structures. These Australian cryptozoön stromatolites, beneath the outer algal mat, consist of a core of detrital carbonate sediment exhibiting ". . . a crude convex-up lamination in vertical cross section and a concentric lamination in horizontal section" (Logan, 1961, p. 522). The reader will note the similarity between these descriptions and those of the stromatolites in the Sconondoa limestone (see figure 24F).

Logan's ecological observations are very significant. His Australian stromatolites are found in the intertidal zone. He concluded that the various forms are responses to the microenvironments within the intertidal area. For example, the flat, algal-laminated sediment and associated low, domal stromatolites are forming in the intertidal mudflat, where wave energy is at a minimum. On the other hand, the discrete heads of cryptozoön types constitute reeflike masses on the exposed headlands. The environment is hypersaline, with the range of salinity from 56 to $65^{0}/_{00}$. Cementation, by the precipitation of aragonite in spaces between detrital grains, is believed to be rapid in order to prevent collapse of the high-relief structures. The translatory wave motion results in the elongation of some domes parallel to the water movement (i.e., perpendicular to the shoreline). The dry upper layers of algal mat in the supratidal zone are cracked and broken into flat fragments that resemble the flat pebbles in the intraformational conglomerates commonly associated with ancient stromatolites.

In conclusion, it is difficult to place the Lockport stromatolites exclusively in any one of the form genera (see figure 24), although they probably are closest to cryptozoön.

DOLOMITIZATION

Dolomite is one of the more important but least understood rock types of pre-Mesozoic times. Much of the mystery is due to the fact that the formation of dolomite is practically nonexistent in present-day seas. Widespread dolomites, such as the Lockport, are believed to have either a primary or a replacement origin. Other more localized dolomites, including those controlled by structures, those formed through weathering, and those precipitated in vugs, will not be considered here.

So far as is known to the writer, the only primary[6] dolomites forming today are in association with evaporites in the southeast of South Australia (Aldermann and Skinner, 1957), and apparently there is some doubt whether these are truly primary (H. A. Lowenstam, 1962, personal communication). The isolated dolomite rhombs reported in deep sea cores (e.g., Zen, 1959) are authigenic rather than actually primary. Even experimentally, true primary dolomite has not been synthesized or precipitated at low temperatures and pressures (Graf and Goldsmith, 1956). The only examples of recent replacement are in some of the Cenozoic reefs in the Pacific that have been altered to dolomite since the Pliocene (Rodgers, 1957, p. 14).

Most dolomites in the geological column are believed to be of the replacement type. In this regard, we must indirectly, at least, invoke the *Law of Uniformitarianism.* Certain textures, structures, and organisms existing now are found associated only with calcite or aragonite. If we find these same features in an ancient dolomite, we apparently are justified in assuming that replacement, i.e., dolomitization, has taken place. Very often, however, recourse must be made to less simple, and more subjective, criteria, such as bedding relationships in the field or textural features in thin section.

Except in the uppermost part of the Lockport, few, if any, evaporites were deposited directly with the dolomite. The abundant snowy gypsum, selenite, and anhydrite in vugs are believed to be secondary. Folk (1959b, p. 153) claimed that the size of primary dolomite grains should be in the order of 2–20 microns. He felt it safe to assume that if a dolomite has a grain size over .03 mm. it must be of the replacement type. Most of the Lockport is coarser than this. Folk, however, pays little heed to the recrystallization of carbonates, particularly dolomite. Recrystallization of fine-grained dolomite undoubtedly would result in a coarser grain size. Furthermore, very fine-grained dolomite need not be primary. Van Tuyl (1916, p. 256) described fine-grained dolomite that had replaced lithographic limestone. Thus, it is highly debatable whether Folk's distinction is meaningful. Some interbedded limestone, dolomite, and mixtures of these "end-members" were observed in both the Gasport and Sconondoa Members. The writer does not feel that such interbedding is indicative of primary dolomite.

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[6] As discussed in this report, primary dolomites refer to those that have precipitated directly from solution.

Although there is little direct support for a primary origin for the Lockport, there is much evidence for replacement.

(1) Bioherms are abundant in the Gasport Member. In places, these are composed of limestone, but more commonly they are dolomitic. We know of no primary dolomite reefs or bioherms forming today.

(2) Stromatolites, a combination of algal structures and algal-bound sediment, are completely dolomitized, except in the Sconondoa Member, limestone facies. Stromatolites may result from the incorporation of carbonate mud within agal thalli or from the induced precipitation of $CaCO_3$ over an algal mat. In the former case, the structures could be dolomitic initially, whereas in the second instance, replacement would be necessary for a dolomitic stromatolite to result. Because of the occurrence of both calcareous and dolomitic stromatolites in the Sconondoa Member, it is believed that the dolomite is a result of replacement.

(3) Thin sections of true dolomite (as determined by X-ray diffraction) show such structures as oolites and pellets in various stages of obliteration (see figure 25).

(4) Fossils, such as crinoid columnals and ostracode tests, are seen in thin section in various stages of replacement by dolomite (see figure 26). Where the same fossils are found in limestone and dolomite beds, they commonly are better preserved in the limestone. Some dolomitized fossils are almost completely obliterated.

(5) Mottled calcareous dolomite and dolomitic limestone is present, although uncommon in the Lockport. It is difficult to conceive of these textures having formed in a primary precipitate. More than likely they resulted from exsolution of a high-magnesium calcite.

(6) Dolomite rhombs in dolomitic limestone commonly show replacement relations with respect to the calcite groundmass.

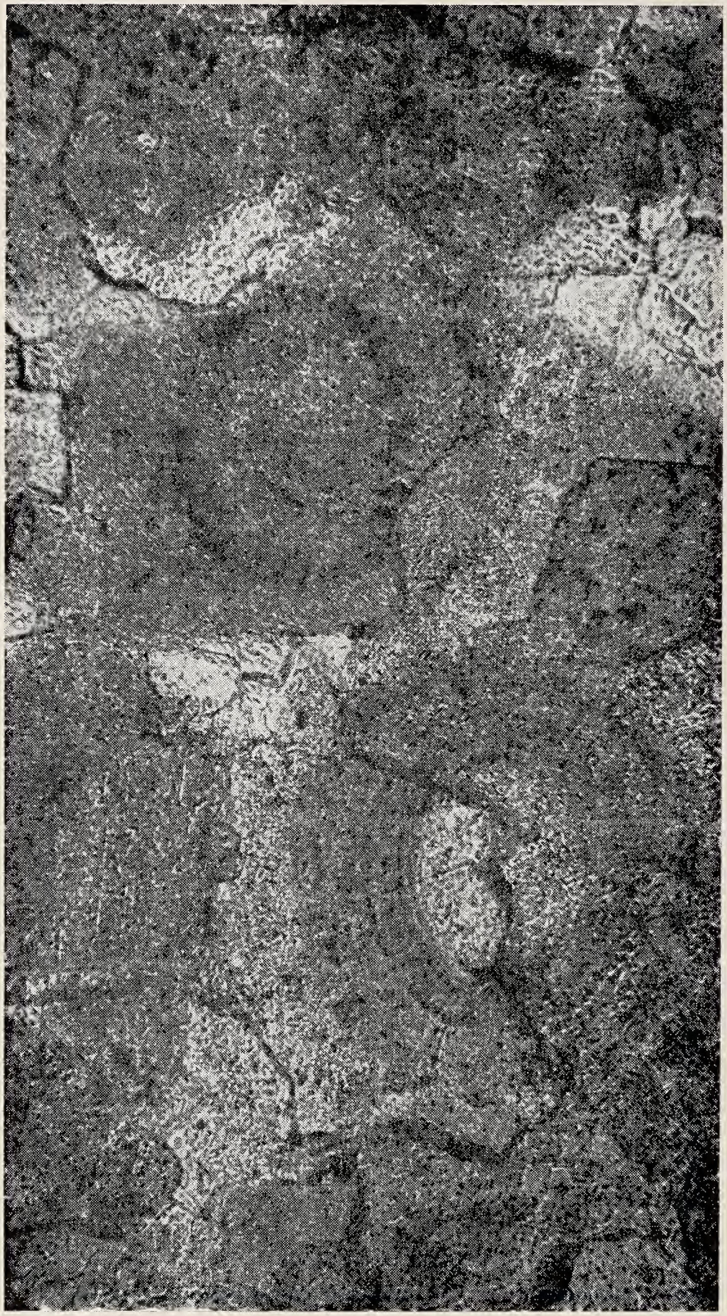

FIGURE 25. Photomicrograph. Relict oolites in dolomite of Sconondoa Member. Note dolomite grains cutting across these ghosts (plane polarized, X100).

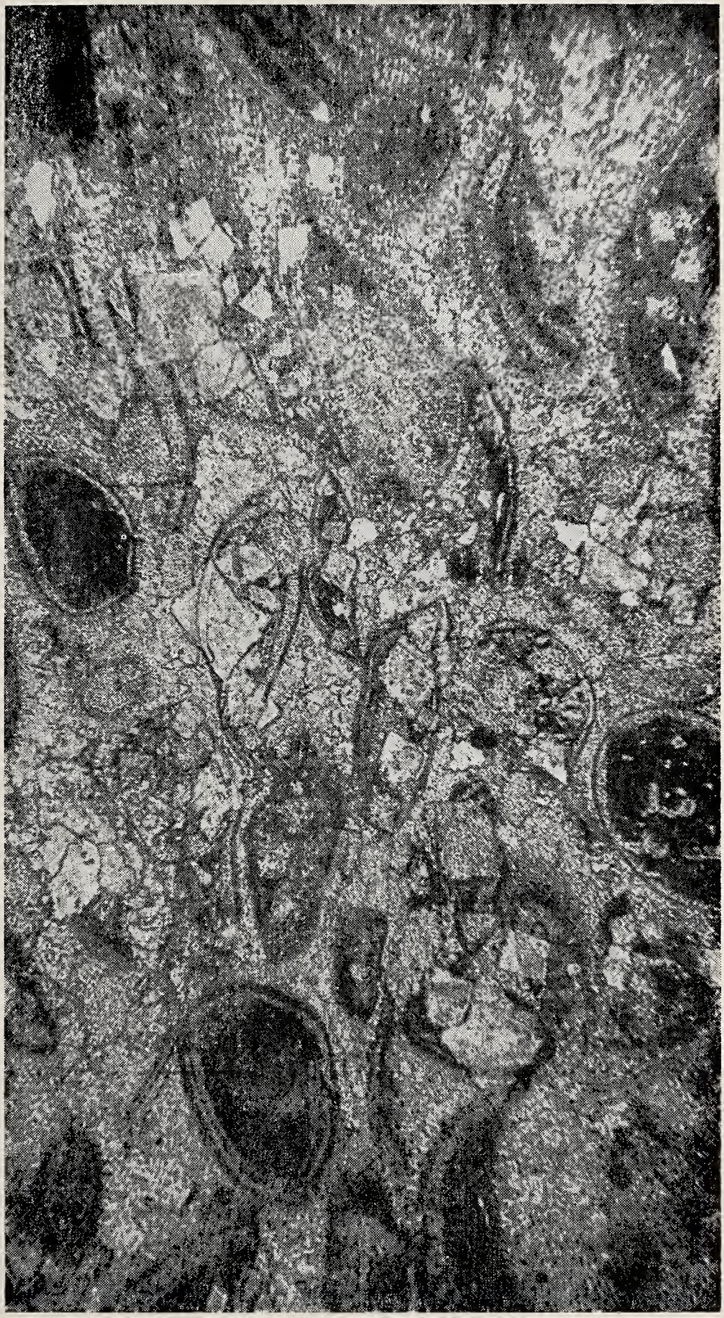

FIGURE 26. Photomicrograph. Ostracode *Eukloedenella* in dolomitic limestone of Sconondoa. Note replacement relations of dolomite rhombs with respect to ostracode tests (plane polarized, X30).

All available evidence seems to point to a replacement origin for the Lockport, and the writer assumes such an origin for the remainder of the discussion.

Fifty-eight samples of the Lockport have been analyzed for calcite-dolomite ratios, as determined through X-ray diffraction, and insoluble residues, in an attempt to see if a correlation exists between these parameters, as noted in other carbonates. Previous reports have shown, on one hand, a correlation between mixed carbonates (for example, dolomitic limestone or calcareous dolomite) and high-insoluble samples (Steidtmann, 1917; Dunbar and Rodgers, 1957) and, on the other hand, a correlation between the more dolomitic and the more highly insoluble samples (Fairbridge, 1957; Bisque and Lemish, 1959). The samples, plotted in a triangular diagram (see figure 27), show an apparent lack of correlation between the two parameters. Two peculiarities about the distribution are the concentration along the " dolomite-insoluble line " and the sparsity of samples in the calcareous dolomite field. The analyses plotted exactly on the line showed no diffraction peak for calcite, although as much as 5 percent might escape detection (Weber and Smith, 1961, p. 130). The suggestion is that beyond a certain point, dolomitization in the Lockport tended to go to completion.

The clastic nature of the Lockport should not be overlooked. Fossil-fragmental layers, oolites, pellets, cross laminations, and intraformational conglomerates indicate that many of the Lockport sediments have undergone some transportation. For the rest of the Lockport, on the other hand, it is indeterminate whether the initial sediment was clastic or strictly a chemical precipitate. There may be only a slight difference between a grain of calcium carbonate that has precipitated from seawater and settled to the bottom and one that has passed through a similar history but, in addition, has been moved by waves or currents. This latter grain is clastic, but the fact may not be ascertainable in the field or even under the petrographic microscope.

Because the Lockport shows evidence of being largely clastic, there arises the question regarding the time of replacement relative to the transportation. Dolomitization may have taken place (1) after precipitation of the calcite grains but before transportation, (2) after transportation and final deposition of the calcite grains, or (3) continuously through the steps described. In most instances, petrographic evidence does not provide an answer. It is believed that the crinoidal and oolitic dolomites probably were dolomitized subsequent to transportation and deposition. Intraclasts having sharp contacts with the matrix probably were transported as dolomite, but in this case the question must be repeated for the sediment from which the

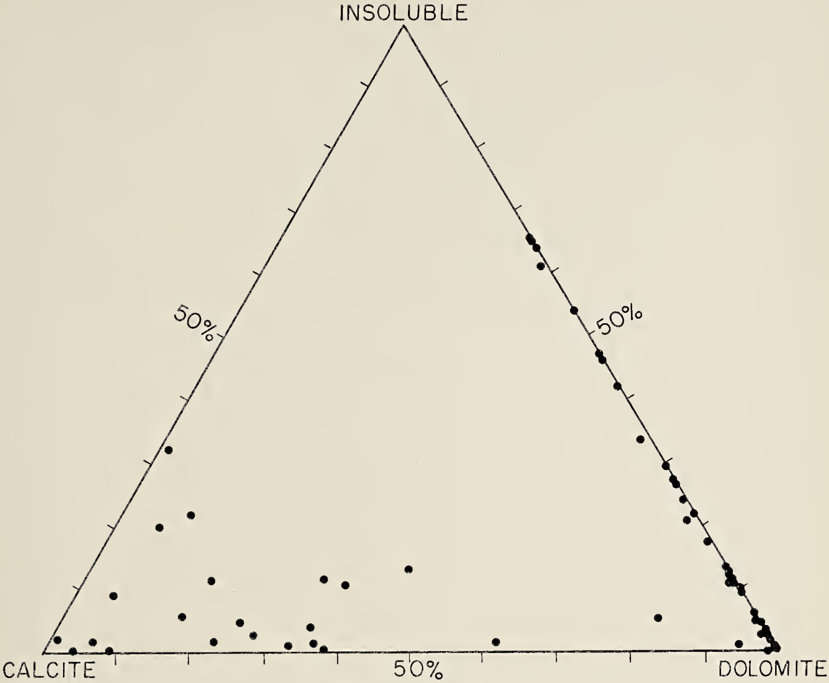

FIGURE 27. Triangular diagram showing composition of 58 Lockport samples, with respect to calcite, dolomite, and insoluble residue end members.

intraclasts were derived. The gradational boundaries of cross laminations suggest dolomitization of a cross-laminated limestone. The common near-obliteration of many textures, structures, and fossils in the Lockport intimates either a late diagenetic dolomitization (Fairbridge, 1957, p. 159) or a dolomitization that began early but continued through much of the period of diagenesis. The mottled dolomite represents dolomitization that for some reason was terminated before completion. Invariably, thin sections of the Gasport and Scondoa limestones show the presence of some dolomite rhombs. Where dolomitization has occurred in the Sconondoa Member (i.e., dolomite facies), it obviously has resulted in a grain size coarser than that in the fine-grained limestone facies.

Groundwater is not believed to be a source of sufficient magnesium to produce widespread dolomite units through replacement. Neither is there evidence to support the theory that river waters can supply the necessary magnesium ions (Fairbridge, 1957, p. 154). Algae may contain high-magnesium calcite, but it is generally agreed that this is an inadequate source of magnesium for dolomitization of the larger units. The source of the magnesium seems to be, unequivocally, seawater.

The writer envisions two possible ways through which the dolomitization of the Lockport may have taken place.

(1) This mechanism is generalized and modified from descriptions by Fairbridge (1957, pp. 149, 152) and Carozzi (1960, p. 269):

In shallow, warm, marine water that is characteristically higher in magnesium than deeper water, organic (e.g., algal) and possibly inorganic precipitation of high-magnesium calcite takes place. The $MgCO_3$ is in solid solution in the calcite and the mineral dolomite has not appeared. The areas of higher $MgCO_3$ concentration form nuclei around which more $MgCO_3$ from seawater is precipitated. A metasomatic replacement of $CaCO_3$ begins and, when the amount of $MgCO_3$ approaches 15 percent, rhombohedra of dolomite form. Once these high-magnesium calcite nuclei have formed, they act as triggers for the remainder of the process, which, if conditions remain unchanged, will continue through the final stages of dolomitization.

(2) The second possibility is termed "seepage refluxion" and was recently described by Adams and Rhodes (1960), using dolomites in the Permian Basin of West Texas as an example:

Hypersaline brines from evaporite lagoons, being more concentrated and having a higher density, sink to the floor of the lagoon and drain seaward down a sloping shelf. This seaward escape of dense brines is called reflux action. If, for some reason, the free refluxion down the slope were checked, the brines might seep downward through the floor of the lagoon into the underlying limestones. These highly alkaline, high-magnesium brines could displace connate waters and provide both a suitable environment for replacement and a means whereby the displaced calcium could be removed.

These are highly theoretical mechanisms. Both may have some applicability in regard to the dolomitization of the Lockport. Algae (stromatolites) and crinoids are abundant in the formation; both are noted for their magnesium content. In the appropriate physical-chemical setting, these organic materials may have supplied the high-magnesium calcite nuclei that triggered subsequent dolomitization.

Overlying the Lockport are the gypsiferous shales, mudstones, and dolomites of the Salina Group. The analogy with the Permian Basin is striking. Brines may have passed downward through the Lockport sediments supplying a magnesium-rich environment conducive for dolomitization. Gypsum is abundant in the Lockport; most of this is secondary[7], being found in vugs and pores. This gypsum undoubtedly has migrated downward from the Salina evaporites. A potential weakness in this explanation for dolomitization of the Lockport is the fact that little, if any, gypsum is found in the formation east of the Macedon quadrangle.

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[7] Drill cores show selenite along partings and in seams in the upper part of the subsurface Lockport. This occurrence probably represents a localized primary precipitation.

Equivalence and Correlation

It is important from the outset that a distinction be made between the term " equivalence " and " correlation." As used herein, equivalence implies a genetic relationship of either lithologic or biostratigraphic units; there is no concept of time inherent in the usage. Correlation, on the other hand, refers to a time equivalence. The emphasis in this project has been in determining equivalents and correlatives in New York State. Wider correlations should be attempted only by a skilled stratigraphic paleontologist who has examined the areas under consideration or who at least has studied fossil collections from these regions. Correlation is not really meaningful when attempted by a local stratigrapher who correlates with sequences hundreds or thousands of miles away by comparing his fossils with faunal lists prepared by others. For these reasons, time relationships beyond New York State will not be treated in any detail.

WESTERN AND CENTRAL NEW YORK STATE

PREVIOUS ATTEMPTS

Vanuxem (1839, pp. 248–249) recognized the equivalence of the " concretionary structures " (stromatolites of this report) in the Lockport of the Third and Fourth Districts. Apparently, his observations, although acknowledged by Hall, have remained unrecognized for more than 100 years. Gillette (1947) set the stage for later correlations by establishing the time-equivalence of the Rochester Shale and the Herkimer Sandstone. Subsequently, the shale and carbonates lying between the Herkimer and the Vernon were " correlated " with the Lockport Dolomite in the west primarily on similarity of stratigraphic position. Reed (1936) considered the Lockport at Clinton (Rome quadrangle) to be equivalent to the lower part of the Lockport at Rochester on the basis of similar high-insoluble content. Although Reed's meticulous work provided valuable data, this writer disagrees with his proposed equivalence. Reed did not sample any of the low-insoluble Sconondoa, which spatially separates the impure sequences mentioned. Cannon (1955, p. 141) apparently regarded the section at Sherrill (Sconondoa-Ilion transition zone of this writer) as equivalent to the entire Lockport at Niagara Falls. This relationship was based on the presence of sphalerite and galena zones. Cannon claimed (p. 150) that these minerals and others were concentrated at ". . . particular breaks or changes." This writer acknowledges the use of mineral assemblages as an aid in determining the gross relationships across the outcrop belt, but is skeptical about the extent and the time-significance of Cannon's zones beyond Orleans County. Leutze (1959), primarily because of opposite changes in thickness of the Vernon and Lockport across the State, suggested that the Vernon of central New York is partially the eastern, shoreward equivalent of the Lockport in the west. Fisher (1960) apparently correlated the Ilion Member with the middle part of the western Lockport.

PROPOSED RELATIONSHIPS

(*see also Plate I*)

The Ilion has been regarded as the probable equivalent of the Lockport, mainly on the basis of a common stratigraphic position above the Clinton and below the Salina. Detailed examinations in the critical area between Sodus and Oneida have revealed much evidence, both lithologic and organic, that supports this provisional correlation. Although the Lockport Formation includes several facies, the lithologic similarities are such that the unit can be traced across the outcrop belt. In the western and west-central areas, from Niagara Falls to Sodus (Palmyra quadrangle), the formation is predominantly dolomitic. Stylolites, medium to thick bedding, medium grain size, carbonaceous shaly partings, vugs, and minerals are ubiquitous characteristics of the Lockport in this area. In the east-central area of this report, the Lockport (i.e., Sconondoa Member) consists of very fine-grained limestone and coarser-grained dolomite. The westernmost part is highly bituminous, but east of the Clyde quadrangle the unit is neither bituminous nor stylolitic. However, there is no doubt that the sequence is Lockport. Interfingering of more typical dolomite with the Sconondoa was observed in the Palmyra quadrangle. Stromatolitic structures characteristic of the upper Lockport west of Macedon are abundant in the Sconondoa Member. The familiar Lockport minerals, such as sphalerite, dolomite, and pyrite, are present in the dolomite facies. The grain size and textures of the Sconondoa dolomite are much the same as those in the members to the west. The intimate association of shale and carbonate in the Oneida quadrangle represents the gradation of the Sconondoa eastward to the Ilion. Much of the dolomite interbedded with the shale of the Ilion is stromatolitic. The dark-gray, spakling lithology is similar to that in the dolomite facies of the Sconondoa. Many of the dolomite layers are vuggy and contain sphalerite, dolomite, calcite, quartz, and pyrite.

Corals and stromatoporoids, the most abundant fossil groups in the western and west-central areas, are of little value in determining the overall stratigraphic relations. *Favosites* is the only coelenterate found east of the Clyde quadrangle. The Ilion Member contains a *Lingula* biofacies, but the lingulids are confined to the Ilion shales and do not continue westward into the carbonates.

One important assemblage of fossils was traced from the western area to the easternmost outcrop in the Ilion Gorge. It consists of stromatolites, the ostracode *Herrmannina*, the pelecypod *Pterinea*, and the brachiopod *Howellella*. The strata containing this assemblage are herein designated as the *Herrmannina-Howellella-Pterinea* Assemblage Zone of the Lockport Formation in New York.

The leperditiid *Hermannina* sp. was found in the Oak Orchard Member at Niagara Falls, Lockport, and Rochester. It is very abundant, together with kloedenellid ostracodes, in the Sconondoa, and is present in the Ilion Member along Steele Creek (Winfield quadrangle). *Pterinea* sp. is present at several outcrops of both the Sconondoa and Ilion Members. The writer found poorly preserved specimens of *Pterinea* in the Oak Orchard Member at the Sodus quarry (loc. 117) and just above the stromatolitic sequence at Niagara Falls. Clarke and Ruedemann (1903, Pl. 5) reported *Pterinea* from their "upper Shelby dolomite" (lowermost Oak Orchard) south of Medina. Specimens of *Howellella* (see also Appendix III), particularly those with smooth flanks (*H.* sp C), are very abundant in the Sconondoa Member. The genus extends eastward into the Ilion Member. *Howellella* sp. B and C. were collected from the lower part of the Oak Orchard at the Penfield quarry (loc. 92). The same forms are present in the easternmost Penfield. They were also reported (as "*Spirifer* cf. *bicostatus*" and "*Spirifer crispus*") by Clarke and Ruedemann (1903, Pl. 4) from both the upper Shelby dolomite at Medina and Arey's Guelph zone at Rochester.

This assemblage was not found in the Lockport below the Oak Orchard Member from Niagara Falls to Rochester. Although it is best developed in the Sconondoa Member, its presence across the outcrop belt indicates an equivalence of the Ilion, Sconondoa, and Oak Orchard Members. The persistence of the above zone through the facies along the strike strongly suggests that the Ilion, Sconondoa, and Oak Orchard Members are not only equivalents but also correlatives. The fact that some of the Penfield grades eastward into the Oak Orchard and Sconondoa suggests that this correlation may include part of this member. This suggestion is supported by the presence of *Howellella* in the Penfield, although the other components of the zone are not present.

The Ilion Member is considerably thinner than either the Sconondoa or the Oak Orchard. Mineralized beds, limonitic shales, and clay seams in the Ilion may represent a significant amount of time. The black, fissile to paper-thin shales in the Ilion may themselves be a stratigraphic condensation of the carbonate section to the west. As Pettijohn (1957, p. 622) mentioned regarding black shales:

> "Their rate of accumulation is perhaps the slowest of all sediments since many feet of clastics or carbonates at one place are the equivalent of few feet of black shale in another locality."

Although there undoubtedly are exceptions to this generalization, this writer believes Pettijohn's comments to be applicable to the Lockport. Thus, the 70 feet of Ilion in the Rome quadrangle is roughly the time equivalent of the Sconondoa and also the Oak Orchard, each of which is nearly twice as thick as the Ilion.

In the Utica and Winfield quadrangles, the increased rate of thinning of the Ilion is due in part to the fact that some of the member grades eastward into the quartzite of the Herkimer. Thus, east of the Ilion Gorge, the Ilion sequence is represented by both the uppermost Herkimer and by part of the Herkimer-Vernon unconformity.

The Ilion-Vernon contact in the Rome and Utica quadrangles is gradational and in places interfingering. This relationship suggests the possibility that in this area, the uppermost Ilion may be equivalent to the lower Vernon.

Another important problem remains. If the Oak Orchard of western New York is a correlative of the Sconondoa and Ilion, and if there is no unconformity between the Herkimer and Ilion, then the lower Lockport of western New York (i.e., DeCew, Gasport, Goat Island, Eramosa, and lower Penfield) is perforce correlative with the upper part of the Rochester and Herkimer of central New York. Direct evidence in support of this correlation is not conclusive and consists of:

(1) As the lower Lockport (i.e., DeCew, lower Penfield) disappears east of Rochester, there is a corresponding increase in thickness of the Rochester Shale. A diamond drill core south of Sodus (loc. 117a, Palmyra quadrangle) reveals crystalline dolomite in the upper part of the Rochester Shale.

(2) The lower Lockport in the western and west-central areas is crinoidal. East of Palmyra, the crinoidal lithology is absent from the Lockport, but the uppermost Rochester and Herkimer in this area are crinoidal.

(3) There is evidence for stratigraphic condensation within the Herkimer, for example, phosphatic and pyritic beds. This, together with facies relationships already presented, indicates that the uppermost Herkimer is younger than the upper Rochester Shale.

Although there is good evidence for an Oak Orchard-Sconondoa-Ilion correlation, more supporting data, preferably faunal, are needed for the suggested correlation of the Lockport in the west with the upper Rochester and Herkimer.

In conclusion, the Lockport in the east (i.e., Ilion Member) is much more closely related to both the Clinton and Salina than has been considered previously.

EASTERN NORTH AMERICA

The new Silurian correlation chart for North America (Berry and Boucot, in preparation) shows many differences from the Lockport correlations presented in the older chart (Swartz, C. K., et al., 1942). This writer does not attempt to reconcile or pass judgment on most of these differences. A few comments are made on some correlations beyond western and central New York. For others, the reader is referred temporarily to the 1942 correlation chart until its successor is published.

The writer concurs with Bolton (1957, p. 59) that the Albemarle Group (Lockport-Guelph) of Ontario correlates with the Lockport of New York. The lower members at Niagara Falls are traced westward into the Niagara Peninsula of Ontario. The " Guelph " east of Hamilton, Ontario, is closer in lithology to the Oak Orchard than to the true, buff, saccharoidal Guelph to the northwest. Nevertheless, it is believed that they all are equivalent. The Guelph fossils in New York and Ontario cross subtle changes in lithology and support the correlation. The writer found *Herrmannina*? in the uppermost Eramosa at Dundas, Ontario. This occurrence, together with the fact that the Erasmosa there is lithologically similar to the Oak Orchard in New York and the " Guelph " of the Niagara Peninsula, suggests that the upper part of the Eramosa may be equivalent to the lower Oak Orchard. With more detailed work on the ostracodes in both the Lockport of New York and the Albemarle Group of Ontario, the relations between these sequences will be clearer. The Albemarle Group is traced around the Michigan Basin and correlatives have been established. Most of these correlations appear sound because the Guelph lithology and fossils are present in the correlatives. These are underlain by carbonates containing a Lockport fauna (e.g., Racine and Engadine Dolomites).

The writer feels that, contrary to the relationships shown on the 1942 correlation chart, the Mississinewa Shale and Liston Creek Limestone of Northern Indiana may correlate with at least part of the Lockport on the basis of similar graptolites (Cumings and Shrock, 1928, p. 592). Correlations with the Appalachians and the Cincinnati Arch region, of necessity, are based only on paleontologic grounds because there is no surface connection with the Lockport to the north. The exact time relations of the Lockport with the Shawangunk, High Falls, and Guymard units of southeastern New York are unsettled at present. The tentative correlation with the McKenzie Formation of central Pennsylvania may be supported by the discovery of the genus *Eukloedenella* in the Lockport. Facies control, however, should not be overlooked (Jean Berdan, 1962, personal communication).

According to the old correlation chart, various Niagaran units in eastern Indiana, western Ohio, central Kentucky, and western Tennessee, such as the Laurel Limestone, Waldron Shale, Louisville Limestone, and Brownsport Formation, are unrepresented by strata in New York. An unconformity between the Clinton and Lockport is supposed to represent these units. As Fisher (1960) pointed out, the differences in the faunal assemblages of the two areas could be due to ecologic control. Most of Amsden's (1949) Brownsport species do not occur in the Lockport. This and other similar observations, however, are weak evidence for placing a significant gap (Swartz, et al., 1942) between the Clinton and Lockport of New York, 700 miles away.

Lockport correlatives have been proposed in Maine and the Maritime Provinces (Bastin and Williams, 1914, p. 9; McLearn, 1924, p. 26; Northrup, 1939, pp. 102–104). Williams (1919, pp. 69, 75) recognized Lockport-equivalent strata in the Lake Timiskaming region. He suggested also that the Lockport and Guelph are represented in the Silurian sequence bordering James Bay and Hudson Bay.

TYPE SECTION (ENGLAND)

The lack of key fossils in the Lockport handicaps any correlation with England. Hall (1840, p. 452) correlated the Lockport with the Wenlock Limestone. Swartz, et al. (1942), considered the Lockport of Ontario (i.e., lower Lockport of New York) as Wenlockian, but correlated it with the Wenlock Shale and the upper part of the Woolhope Limestone. The overlying Guleph was correlated with the Wenlock Limestone.

Neaverson (1955, p. 226) regarded the Lockport as Wenlockian and the Guelph at lower Ludlovian in age. Fisher (1960) showed about the same correlations for this interval in New York State. Boucot and Berry (in preparation) feel it is likely that the Lockport of New York is of upper Wenlock and lower Ludlow age. The presence in the Lockport (loc. 118) of the ostracode *Mirochilina* suggests that some of the Lockport may be Ludlovian.

Paleoecologic and Paleogeographic Considerations

DEPOSITIONAL ENVIRONMENT

UNDERLYING AND OVERLYING UNITS

Gillette (1947, pp. 106–107) suggested a relatively shallow-water origin for the fossiliferous Rochester Shale. It was regarded as an offshore facies that grades eastward (shoreward) to the ". . . marine, beach, and semicontinental sandstones of the Herkimer."

The more problematical paleoecology of the overlying Vernon Shale has been discussed frequently. Alling (1928), Fisher (1957), and Leutze (1959) agreed that the Vernon represents a deltaic deposit. This theory is favored over those regarding the Vernon as a residual soil or loess deposit (see Fisher, 1957, p. 12). Alling (1928, p. 45) commented that ". . . it is the delta silt deposit of a river flowing from a desert area into playa lakes or lagoons." Fisher (1957, pp. 11–12) conceived of the Vernon as follows:

> ". . . a deltaic river deposit infringing on a large multiple restricted lagoon or series of small, restricted lagoons . . . Mudcracks suggest deposition in a littoral zone or one in which the floor of the sedimentary environment (lithotope) is alternately exposed and flooded. This could imply a tidal zone of a relatively large body of water, or a restricted lagoonal type of environment. The writer prefers the latter supposition because of the coexistence of evaporites such as gypsum and halite, within the Late Silurian environments."

LOCKPORT FORMATION

Depth of water. Both organic and physical evidence are undeniably indicative of a shallow-water origin for all facies of the Lockport. The Gasport bioherms, with a coral-stromatoporoid framework, strongly suggest a shallow-water environment. Shallow-water, benthonic fossils (such as brachiopods, bryozoans, and corals) are present throughout the Lockport. Stromatolites now forming in Australia are intertidal in occurrence (Logan, 1961). The presence of stromatolites in the Oak Orchard, Sconondoa, and Ilion Members suggests a very shallow sea in central and western New York during much of Lockport time.

Physical evidence is equally as impressive. The fossil-fragmental nature of the Gasport and higher zones is typical of a unit deposited above wave base. According to Folk (1959a, p. 1) such a biosparrudite is ". . . analogous with a well-sorted, clay-free sandstone and similarly formed in the loci of vigorous currents." Cross laminations, intraformational conglomerates, pellets, and ripple marks are common and, considered together, constitute good evidence for deposition above wave base. Fillings of incomplete mud cracks (see also Shrock, 1948, pp. 192–194) are present in several layers in the Sconondoa Member. At one locality (loc. 156, Rome quadrangle), complete mud cracks were seen in the basal Vernon, just above the gradational contact with the Ilion. These structures probably represent subaerial deposition.

The oolites and edgewise conglomerates associated with the stromatolites were formed in shallow water. Most authorities (Illing, 1954; Pettijohn, 1957; Carozzi, 1960) agree that oolites form in an agitated environment. In view of the presence of other desiccation features, this writer believes that most of the intraclasts in the conglomerates came from a tidal flat and may represent the cracking of exposed algal mats or sheets (Ginsburg, 1957, pp. 92–95; Logan, 1961, p. 527). One lithotope, that of the dark, paper-thin shales in the Ilion, could be an exception. However, paper-thin parting is not necessarily indicative of deep water but only of quiet water, perhaps in a protected embayment. The intimate association of these shales with the shallow-water stromatolites and the presence of *Lingula* indicate that the shales also were deposited in shallow water.

Salinity. Although methods of determining paleosalinities are being investigated, only generalities may be made now concerning the salinity of the Lockport sea. Modern bryozoans are relatively euryhaline, but are best adapted to normal or below-normal salinity (Duncan, 1957, p. 788). Reef corals tolerate salinities between 27 and $40^0/_{00}$ but their greatest development is at normal salinity (Vaughan and Wells, 1943, pp. 57–58). Salinity comparable to that of the present ocean probably prevailed during Gasport time, when bioherms were built by stromatoporoids and corals. Between the bioherms, bryozoans are abundant. Above the Gasport, however, bioherms are uncommon or absent.

The stromatolites are present in the upper part of the Lockport in the west and throughout the sequence in the east. In Australia, these structures are forming under prevailing hypersaline conditions with salinities ranging from 56 to $65^0/_{00}$ (Logan, 1961). If we appeal once more to analogy and in addition consider the evaporites of the overlying Salina, the implication is strong that the salinity of the Lockport sea increased through time. Although most of the gypsum and anhydrite occurring in vugs is believed to be secondary, selenite seams and partings in the uppermost part of the subsurface Lockport probably represent a primary occurrence. The presence of such fossils as *Pterinea* and leperditiids does not argue against an above-normal salinity, because they also occur in the overlying Vernon.

It is believed that the formation of dolomite, either as a primary precipitate or as a replacement, is promoted by an increased salinity (Steidtmann, 1917, p. 447; Fairbridge, 1957, pp. 140, 154; Pettijohn, 1957, p. 424; and others).

Temperature. The corals and stromatoporoids constitute a warm-water fauna. Dolomitization is thought to be favored by a warm-water environment (Steidtmann, 1917, p. 446; Fairbridge, 1957, p. 152). Furthermore, the precipitation of the original limestone would have been facilitated in warm water. Higher-than-normal temperatures undoubtedly played a large role in the evaporation and subsequent deposition of evaporites in the overlying Salina. Seasonal changes may have been the cause of banding in some coral and stromatoporoid colonies.

Light. Except for some local turbulance, the abundance of corals and stromatoporoids indicates that the sea was relatively clear during the deposition of the low-insoluble units. In the more impure DeCew, Eramosa, Penfield, and Ilion, the coelenterate fauna is greatly impoverished, the stromatoporoids apparently being the least tolerant.

Hydrogen-ion concentration (*pH*). According to the work of Krumbein and Garrels (1952), a pH of over 7.8 causes precipitation of calcite, whereas a lower value promotes solution. Assuming that the main mass of the Lockport originally was a limestone, we can set a lower limit on the pH of the environment at the time of deposition. Most authorities favor a more alkaline solution than normal seawater for dolomitization. If such is the case, dolomitization should be favored in shallow, near-shore waters where not only magnesium is concentrated (Fairbridge, 1957, p. 164), but also where photosynthesis extracts carbon dioxide from the water, thereby elevating the pH. The presence of stromatolites in this alkaline environment would not pose a serious problem; most blue-green algae are best adapted to a pH above 7.8 (J. R. Vallentyne, 1962, personal communication).

Oxidation-reduction potential (*Eh*). It appears that much of the Lockport was deposited under reducing conditions. Carbonaceous partings and bituminous dolomites are common from Niagara Falls to Clyde. The black color of the shales in the Ilion Member undoubtedly is due to the organic and pyritic content. The sulfide minerals, sphalerite, galena, and some pyrite, are present in the western dolomite sequence. Pyrite, chalcopyrite, and sphalerite are abundant in the Ilion Member. Platt (1949), from a spectroscopic study, concluded that the galena and sphalerite in the Lockport resulted not from an inward migration but rather from a concentration of indigenous sulfides. Cannon (1955) also found that the Lockport is enriched in sulfide minerals and suggested that (p. 157) ". . . at least part of the sulfides crystallized early in the history of the rocks, possibly even during the diagenesis of the carbonate muds." That a reducing environment for the bottom deposits is implied by the presence of organic matter and sulfides, particularly pyrite, seems certain (Krumbein and Garrels, 1952; Pettijohn, 1957, p. 622). ZoBell (1946) stated that fine-grained bottom deposits rich in organic matter are characteristically reducing environments. Cannon (1955, p. 147), in regard to the Lockport, envisioned a partial stagnation of the bottom and a negative oxidation potential under which hydrogen sulfide and sulfur were present and ferrous iron and sulfides were precipitated.

Excluding diagenetic changes, in order for organic material to be preserved and for sulfides to be precipitated, the zero Eh level must be at or above the sediment-water interface. It is unlikely that this zero Eh level remained stationary in time and space during Lockport deposition. For example, the lighter-colored Gasport contains little organic matter and is not as rich in sulfides as most of the other members. The Gasport also shows evidence of profuse benthonic life, including bioherm-building forms. It is presumed, in this case, that the zero redox level was somewhere below the surface of the deposits, so that the uppermost sediments accumulated in an oxidizing environment. During the deposition of the main mass of the Lockport, this level was nearly coincident with the sediment-water interface, in places and at times moving below or above. It probably was slightly above the sediments during the formation of the more mineralized and bituminous strata. The presence of the benthonic corals, stromatoporoids, and brachiopods indicates that at times oxidizing conditions extended from sea level down to at least the surface of the sediments. Most of the organic, pyritic, black shales and dolomites in the Ilion Member accumulated with the zero Eh level above the depositional interface. Fossils in this member are rare, with the exception of the linguloids, which are noted for being a very hardy group. *Howellella* and *Pterinea* occur in lighter shales that probably represent less reducing conditions.

It has been pointed out that much of the Lockport shows evidence of having been deposited above wave base. It might be argued, then, that the uppermost sediments should be oxidized. There are several possible explanations for the restriction of oxygen from the upper sediments, even in an agitated environment:

(1) In a restricted embayment with higher-than-normal salinity, the oxygen is depleted a short distance below the surface. Subsequent mixing might be inhibited by a density stratification. This possibility is not favored, because it is apparent that at least the waters above the depositional interface contained sufficient oxygen to sustain the observed benthonic fauna.

(2) An abundance of decaying organic matter might result in reducing conditions right up to the depositional interface, despite circulating waters.

(3) In places, waves may have been hampered by abundant algal or seaweed growth and circulation of oxygen generally would have been restricted from the bottom sediments (Shepard, 1959, p. 258).

It is not wise to place much credence in comments regarding the paleoecology of dolomite because of their highly theoretical nature. Nevertheless, it is interesting to note that various students of dolomitization have claimed that the presence of ferrous iron and bitumen in many marine dolomites and their absence in limestones indicates that dolomite is formed in a reducing environment (Steidtmann, 1917; Fairbridge, 1957). It is suggested here that the dolomitization of the Lockport was favored by reducing conditions.

Summary. The preceding paleoecological observations and speculations suggest that in Lockport time (exclusive of the Gasport) there existed a set of conditions somewhere between those postulated by Krumbein and Garrels (1952) for a humid restricted and an arid restricted environment. The salinities usually were not high enough to cause precipitation of evaporites or to exclude life, the decay of which was essential for the reducing capacity. Apparently, the Lockport sea in post-Gasport time was a shallow-water body with somewhat restricted circulation. As late Niagaran time progressed, the waters became more saline and by early Cayugan time were hypersaline. Organisms could not tolerate the increased concentration, and reducing conditions ceased in the bottom sediments. In the eastern reaches of the shallow embayment, the black shales of the Ilion probably accumulated in a more restricted environment. The salinity may have been less, however, owing to the proximity to land and the influx of fresh water.

PROVENANCE

Prevalent today is the time-honored concept of an eastern source for the post-Cambrian Paleozoic sediments in New York State. It is highly probable that the main source was to the east during this time. Once correlations have been established, it is a monotonous rule that clastic units increase in both grain size and thickness to the east. Carbonate units commonly grade to clastics in the same direction.

Conceding these obvious points, the writer feels that too many geologists have been reluctant to consider the influence of the northern shoreline on Paleozoic sedimentation. Such an investigation requires a cautious approach, because any effect by the northern shoreline generally would be masked by the greater influence from the east or southeast. There is another deterrent. The Paleozoic units under consideration crop out along an east-west line that is nearly perpendicular to the eastern source. This situation restricts a field examination of the rock units perpendicular to the northern shoreline. Nevertheless, a critical inspection of suitable units along the outcrop belt might provide information regarding sedimentation control from the north. The ideal unit for a study of this kind would be a widespread carbonate unit, such as the Lockport Formation.

Field studies in this connection, combined with insoluble residue analyses, have revealed some interesting relationships. Certain members, including the DeCew, Eramosa, Penfield, and Ilion, are high in insoluble content (see figure 28). It is apparent that the muds that formed the Ilion were brought in from the east. The Penfield Member, however, disappears west of Brockport and east of Palmyra. Its basal unit is a dolomitic sandstone and, except for a few beds, the upper part contains considerable amounts of quartz. The low-insoluble Sconondoa separates the Penfield and the Ilion. It is unlikely that the terrigenous quartz was delivered to the Penfield through a process of bypassing from the east across the 60-mile stretch of relatively pure carbonates. Rather, it appears that the source was to the north. The quartz grains in the Penfield are strained, suggesting a crystalline

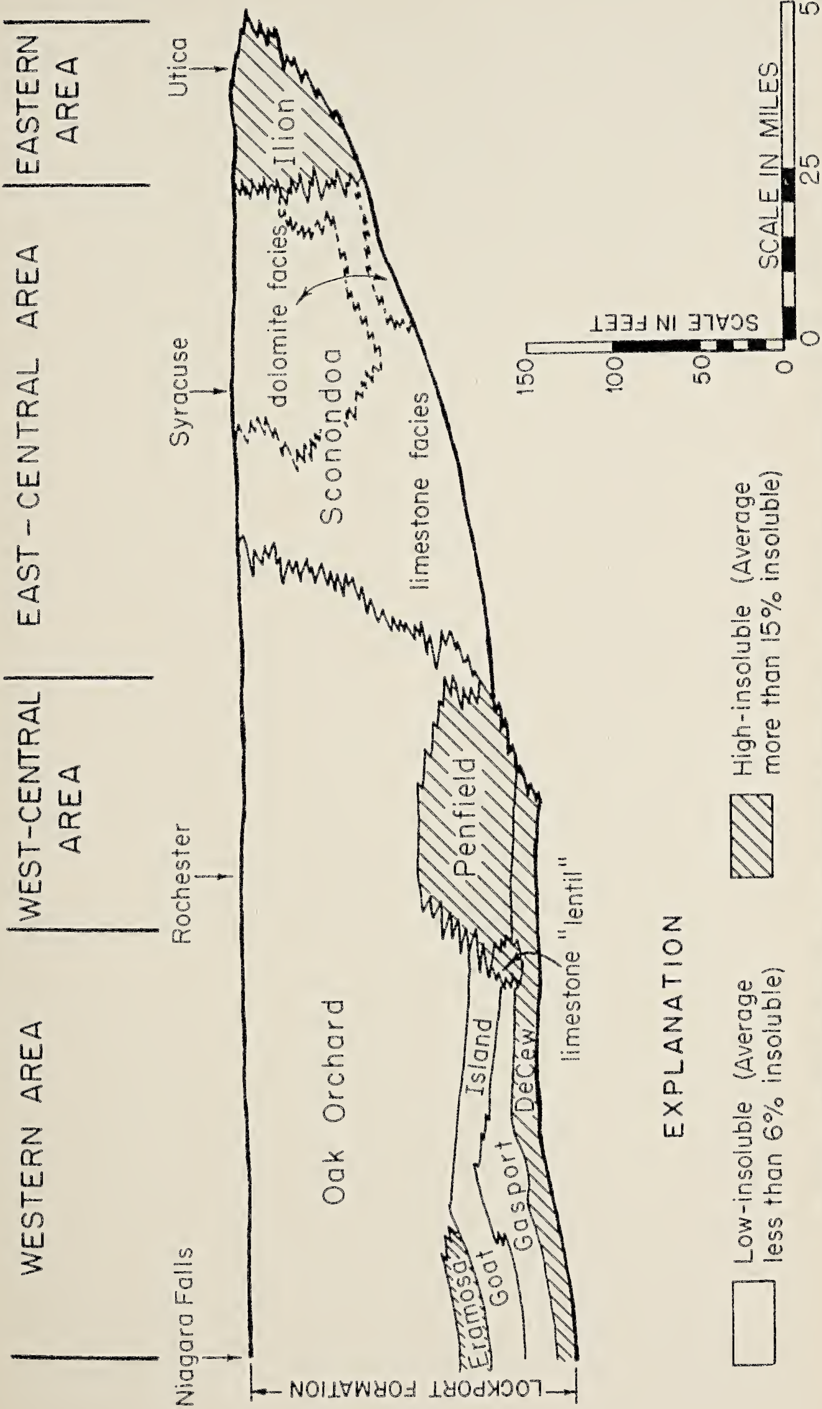

FIGURE 28. High-insoluble and low-insoluble members of the Lockport Formation in New York State.

source. At one exposure in Rochester, R. G. Sutton (1961, personal communication) found cup corals oriented along a north-south line with the calices opening to the south, suggesting a current direction from the north.

The Eramosa, or at least its high-insoluble character, does not reach eastward to the Medina quadrangle in New York. It extends far westward into Ontario, however, where it is argillaceous and thicker. The source of terrigenous clastics probably was to the north or northwest of the Lockport sea in New York. The insoluble residues of the DeCew are highest and coarsest between Albion and Rochester. The unit probably passes eastward into the finer clastics of the Rochester Shale. It would appear that the main source of the insolubles was to the north or northwest. Laird (1935) concluded that the silica for the chert in the Lockport came from the Precambrian crystallines of the Canadian Shield.

The Herkimer and Ilion lithologies and structures indicate their proximity to and control by the eastern shore. The elongation of stromatolites at College Hill (loc. 158) in the Rome quadrangle is nearly east-west, or perpendicular to the shore. The orthoquartzite of the Herkimer in the Winfield and Richfield (adjoins Winfield on east) quadrangles may represent a beach environment.

It was observed that the altitudes of both the upper and lower Ilion contacts increase noticeably to the east in the Rome and Utica quadrangles. This increase suggests one of two possibilities:

(1) The Adirondack Arch, the northern part of which generally coincides with the eastern limits of the Lockport and Herkimer, underwent uplift in post-Niagaran time, or

(2) the Adirondack Arch was a " high " during Niagaran time and the Ilion shales and the Herkimer sandstones were deposited off the western flank.

So far as is known, little has been reported concerning the provenance of the Vernon Shale. It differs from the underlying Ilion in two major respects. The red color of the Vernon represents oxidation, probably at the site of deposition. Its lack of fissility undoubtedly is due to a more rapid accumulation than that of the Ilion. The writer realizes that these differences are not necessarily the result of a different source for the two units, but the maximum thickness of the Vernon is west of the type section at Vernon, N.Y. (Leutze, 1959, p. 35), suggesting the possibility of a more westerly source for the terrigenous muds and silts. Thickness data, however, may be misleading owing to complications introduced by unconformities and facies changes.

In summary, control on Lockport sedimentation was exerted both by low-lying land to the north and by an eastern source (Adirondack Arch?). High insoluble units, exclusive of the Ilion Member, represent time and space relationships to drainage systems entering the Lockport sea from the north. The eastern source was more active during the deposition of the Clinton Group. For much of Lockport time, however, only fine silt and clay were supplied by this eastern source and its effect was not important west of Oneida.

Economic Aspects

The economic aspects of the Lockport may be considered in two categories: (1) oil and gas, and (2) rock products. No extensive oil and gas finds have been made to date in Lockport rocks of New York State. Considering the bituminous and organic characteristics of the unit, it is conceivable that a potential source of oil and gas existed within the unit itself. The fact that some asphaltic inclusions have been found along the outcrop belt suggests that some liquid hydrocarbons have migrated up dip. Perhaps a much greater amount has been lost at the exposures (Platt, 1949, p. 12). However, local variations of dip, bioherms, or other facies relationships in the subsurface might provide traps. In fact, gas has been sealed in " coral reefs " of the Lockport near Geneva, N.Y. (Gillette, 1940, p. 98).

By far the most important use of Lockport rocks are for highway and construction materials and for agricultural lime. Early settlers recognized the economic value of the Lockport. The Gasport was quarried for decorative purposes, and the DeCew was used as a natural cement. At numerous places south of the escarpment one sees the remains of small quarries and limekilns in which Lockport dolomite was burned for lime.

Today, the quarry industry is concentrated in the western and west-central parts (as defined in this report) of the outcrop belt. The General Crushed Stone Company operation near Sodus is the easternmost quarry. The locations of the active quarries and the sections in each are given in appendices I and II, respectively. Following is a brief description of each quarry.

Niagara Stone Corporation quarry, Tonawanda quadrangle (loc. 9). The total section is 77 feet thick. The base of the quarry is in the Eramosa Member; the section includes 12 feet of high-insoluble (one sample was about 15 percent insoluble) Eramosa overlain by 65 feet of low-insoluble, bituminous, stromatolitic dolomite assigned to the Oak Orchard Member. Little, if any, limestone is present.

Frontier Dolomite Concrete Products Corporation quarry, Lockport quadrangle (loc. 29). Rock products are crushed stone, bituminous concrete, asphalt filler, and agricultural lime. The quarry floor is at or near the base of the DeCew. The section consists, in ascending order, of 8.5 feet of argillaceous DeCew dolomite; 29.5 feet of Gasport, the lower half of which is low-insoluble, dolomitic limestone and the upper half a higher insoluble dolomite with bioherms and bioherm-detrital beds; and 24 feet of Goat Island, a low-insoluble, saccharoidal dolomite.

Royalton Stone Corporation quarry, Lockport quadrangle (*loc. 37*). Rock products are concrete aggregate, fluxing stone, agricultural lime, crushed stone, and railroad ballast. The quarry floor is near the top of the DeCew dolomite; the section is largely Gasport, a crinoidal, low-insoluble dolomite containing bioherms and flank beds composed of more highly insoluble dolomite. Little limestone is present in the 30-foot section.

Clarendon Stone Company, Inc., quarry, Albion quadrangle (*loc. 57*). Rock products are crushed "limestone," asphaltic concrete, and blacktop. The floor of the quarry is in the uppermost Rochester Shale. A 55-foot section, dipping west at 5°, includes 4 feet of Rochester dolomitic shale; 13 feet of DeCew, a very high-insoluble dolomite and limestone; 13 feet of Gasport, a crinoidal dolomite containing more highly insoluble bioherms with flank beds; and 25 feet of chert-bearing, crinoidal dolomite of the Goat Island Member.

Concrete Materials, Inc., quarry, Bergen quadrangle (*loc. 63*). The section includes 11 feet of argillaceous limestone and dolomite assigned to the DeCew and 21 feet of high-insoluble (2 samples average 27 percent) limestone and dolomitic limestone with shaly partings.

Dolomite Products Company, Inc.-Gates quarry, Rochester quadrangle (*loc. 80*). Rock products are chiefly asphaltic materials. The floor is at or near the base of the Gates Member of the Rochester Shale. The 100-foot section is as follows: 18 feet of argillaceous, in places bituminous, dolomite (Gates); 12 feet of enterolithic, high-insoluble (more than 20 percent insoluble) DeCew dolomite; 52 feet of quartzose dolomite (Penfield); and 18 feet of low-insoluble, bituminous dolomite (Oak Orchard).

Dolomite Products Company, Inc.-Penfield quarry, Macedon quadrangle (*loc. 92*). An 80-foot section begins in the lower dolomitic sandstone of the Penfield Member, which is overlain by 54 feet of quartoze dolomite with carbonaceous shaly partings; the uppermost 17 feet comprises the lower part of the Oak Orchard Member, which is a low-insoluble, bituminous dolomite with carbonaceous shaly partings and numerous mineralized vugs.

General Crushed Stone Company quarry, Palmyra quadrangle (*loc. 117*). The section, assigned wholly to the Oak Orchard Member, comprises 65 feet of low-insoluble (average less than 2 percent), bituminous dolomite with a profusion of stylolites and shaly partings; practically no limestone is present.

In addition to these operations, two prospective quarries are in different stages of development. The Dolomite Products Company, Inc. has begun operation in the Town of Walworth (Macedon quadrangle; loc. 97a). The writer studied a core showing a section of 42 feet of quartzose dolomite (Penfield) with stylolites and shaly partings, overlain by about 10 feet of saccharoidal dolomite (Oak Orchard). The overburden is 8 feet thick at the site. As this report was written, John Petrossi, owner of Clarendon Stone Company, was in the process of diamond drill exploration in the Town of Marion (Palmyra quadrangle) in the hopes of beginning operations. Cores were unavailable for study.

As a general rule, and particularly west of Brockport, overburden increases in thickness from north to south across the outcrop belt. For example, in the vicinity of Lockport and Gasport, the Lockport is covered by a thin mantle of drift. Along the southern part of the outcrop belt at the same longitude, the unit is overlain by as much as 60 feet of drift including lake sediments. The overburden at the operating quarries is seldom more than 10 feet thick. The quarries at Gates, Penfield, and Sodus lie well south of the northern limit of outcrop. In this area the drift is more patchy, although there is still a tendency to thicken toward the Salina outcrop belt. The Sodus quarry and the prospective quarries in the Towns of Walworth and Marion are situated in the low areas between drumlins, where the bedrock is nearest the surface. Local groundwater drilling records provide the best means of determining the thickness of overburden in any given area.

Potential quarry operators should keep in mind some of the characteristics of the various members of the Lockport in the western and west-central areas. The dark, bedded facies of the Gasport is a relatively high-insoluble unit. The quarries at Lockport and Gasport expose bioherms and these darker beds between. An exploratory core penetrating a bioherm would obviously present a different section than one penetrating the darker, finer-grained beds. The insolubles in the Gasport are not extremely high, the highest determined being 18 percent. The Eramosa averages about 20 percent insoluble, whereas the quartzose dolomite and dolomitic sandstones of the Penfield are very impure. Because the insolubles are composed of predominantly silicate minerals, these units are to some extent " hydrophilic " (Krynine and Judd, 1957, p. 338); that is, they have a low bitumen sorption. The possibility of " stripping " is a consideration if these high-insoluble beds are to be used in bituminous mixes.

Chert-bearing zones in the Lockport are worthy of consideration. Chert occurs sporadically in the lower part of the Goat Island Member. Exposures of this interval are not numerous; of those studied, the only places where chert is abundant is at the Clarendon Stone Company quarry (loc. 57). There are chert nodules higher in the Lockport, particularly in the upper Goat Island and lower Eramosa at Niagara Falls, and in the lower part of the Oak Orchard between the Lockport and Palmyra quadrangles. These zones are not thick, but their occurrence is mentioned because of the possibility of a reaction between the chert and the alkalies in a cement which could result in failure of the concrete.

With the possible exception of chert beds in the Oak Orchard, this unit is exploitable for road materials. The Oak Orchard underlies the southern part of the outcrop belt, however, and in the western area it is commonly covered by a considerable thickness of drift and alluvium. Bedding is medium to thick; as a rule, the joints are not closely spaced. Shaly seams and stylolites coated with argillaceous material are numerous and locally increase water sorption. The ubiquitous vugs could possibly cause drainage problems after quarry operations have begun.

The easternmost Ilion Member consists mostly of shale and will not be considered further. The Sconondoa Member, however, does offer some possibilities. Small, abandoned quarries are scattered across the Sconondoa belt of outcrop between Sodus and Oneida. Most of these are nearly filled with water, suggesting a shallow water table which might result in costly pumping operations. The few outcrops strongly suggest that between Sodus and Syracuse most of the Sconondoa is a very fine-grained, mostly medium-bedded limestone. Interbedded dolomites are apparently minor. Shaly seams and partings are common. X-ray analyses and thin-section petrography reveal the presence of small amounts of dolomite in these limestones. Insoluble residues are low, consisting chiefly of quartz. At Syracuse and eastward to Oneida a low-insoluble, coarser-grained dolomite constitutes most of the mass of the Sconondoa, although the limestone facies is also prominent in the Oneida quadrangle. Both limestone and dolomite facies become more insoluble in the Oneida quadrangle, where the Sconondoa is interbedded with shales of the Ilion. The writer suggests more detailed examination of the Sconondoa, particularly of the limestone facies between Sodus and Syracuse, with the idea of quarry possibilities. Conceivable deterrents in the use of the limestone are the drainage conditions, argillaceous partings and seams, and the presence of thin to shaly bedding in many of the sequences.

The sparsity of exposures reflects the fact that drift mantles most of the bedrock. No detailed study has been made of the thickness of overburden. In the drumlin area the thinnest cover is in the lowlands along stream courses. Commonly, variations in thickness of overburden are considerable within a local area. For example, along the Ridge Road in the Chittenango quadrangle the Sconondoa is covered by up to 30 feet of overburden, whereas a short distance away (loc. 143) the unit is at the surface of the ground.

Transportation facilities are generally good across the outcrop belt of the Sconondoa. Numerous paved and dirt roads serve the area in which most of the stone would probably be used. The main line of the New York Central roughly parallels the outcrop belt a short distance to the south, and several smaller rail lines cut transversely across the unit.

No specific quarry site is proposed. Localities 122, 126, 130, 131, 132, and 133 are abandoned quarries in the limestone facies. The overburden in the vicinity of most of these is not great. The same is true for localities 138, 139, 140, 143, 144, 146, 147, and 150 in the dolomite facies.

Appendix I

LOCATION OF SECTIONS AND OUTCROPS

It is believed that all the important, accessible exposures of the Lockport have been examined. The exposures are numbered in order from west to east, and their geographic locations within a particular 15-minute quadrangle are briefly described.

NIAGARA FALLS

1. Across Niagara Escarpment along Lewiston Road south of Lewiston (see also figure 29 for the location of this and localities 2–7, the latter representing temporary exposures in the now-completed Niagara Power Project)
2. Continuous exposure along the south haul road leading from the Niagara Power Project generating plant 1.7 miles south of Lewiston
3. Along ramp leading into canal excavation just west of reservoir pump-generating plant, Niagara Power Project
4. Along ramp leading into work area No. 2, immediately south of railroad crossing, Niagara Power Project
5. Conduit excavation along edge of backfill, about 0.5 mile south of loc. 4
6. Exposure along edge of backfill, about 0.5 mile north of intake area, Niagara Power Project
7. Intake area on Niagara River, Niagara Power Project

TONAWANDA

7A. Diamond drill core (Bureau of Soils) from hole drilled at north end of Grand Island Bridge (north) along Buffalo Road

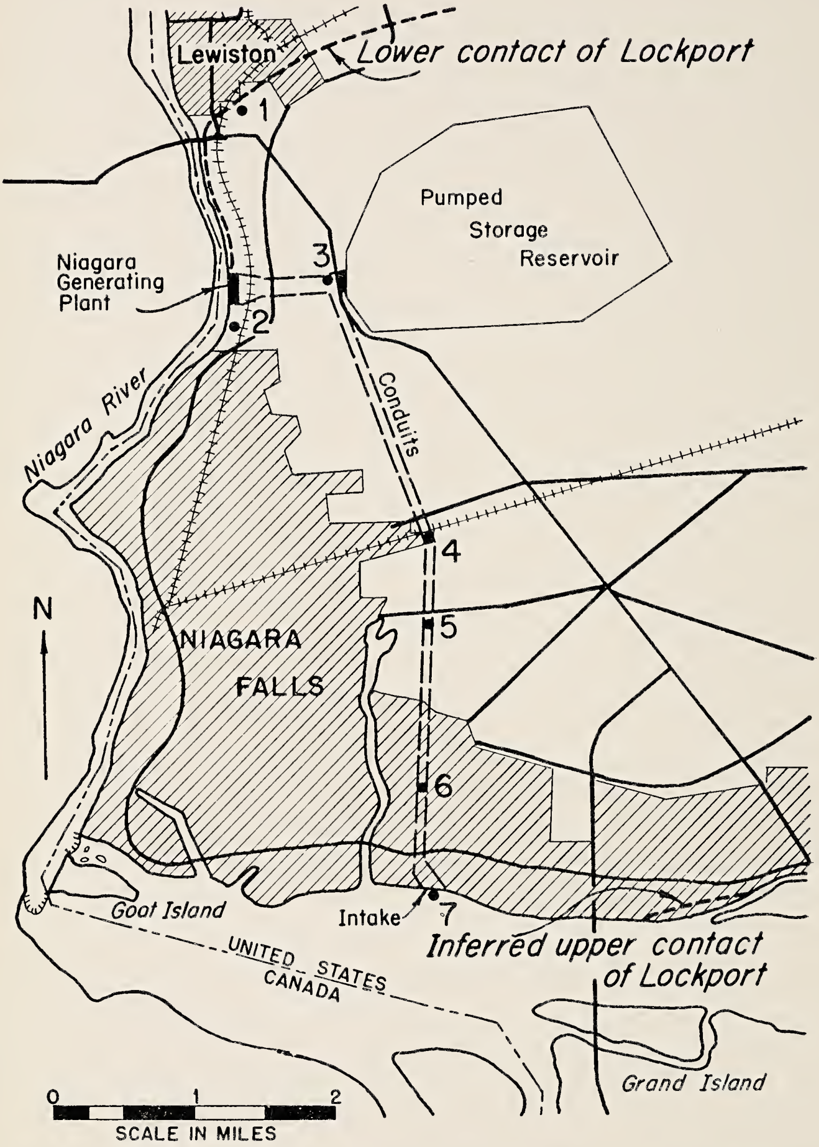

FIGURE 29. Location of Lockport sections in and near Niagara Power Project operations, Niagara Falls, N.Y. (base map courtesy of Niagara Power Project officials)

8. Along stream north of Upper Mountain Road, 0.9 mile south of Model City
9. Niagara Stone Company quarry, 0.3 mile north of Lockport Road, 1.9 miles east of Pletchers Corners
10. Along Bergholtz Creek just southwest of six corners, 1.5 miles south of Walmore
11. In stream bed north of Lockport Road, 0.4 mile east of three corners at Walmore
12. Small ravine 0.3 mile north of Upper Mountain Road, 1.3 miles west of Pekin
13. Stream gully a few feet north of Upper Mountain Road, 0.45 mile west of Pekin
14. Section below overhead along Route 429, northern part of Pekin
15. Abandoned quarry behind greenhouse 0.1 mile west of Ward Road, 0.5 mile south of railroad crossing at Sanborn
16. Diggings from excavation for house, 0.15 mile southeast of Pekin overpass
17. Ditching for waterline along Lockport Road northeast and southwest of Shawnee
18. Exposure on escarpment along Shawnee Road 0.1 mile north of Upper Mountain Road
19. Roadcut section across escarpment 0.3–0.4 mile south of Cambria Center
20. Abandoned quarry 0.15 mile south of Saunders Settlement Road, 1.3 miles west of Comstock Corners
21. Along Thrall Road, 0.35 mile west of intersection with Upper Mountain Road
22. Abandoned quarry just south of Saunders Settlement Road, 0.23 mile west of four corners, 0.5 mile south of Lockport Junction
23. Roadcut across escarpment, 0.5 mile south of Hickory Corners (Route 270)

LOCKPORT

24. North-south road over escarpment west of Niagara Sanatorium, about 2 miles west of Lockport
25. Dump on west side of Barge Canal opposite Dunnigan Road
26. Dump on east side of Barge Canal just north of bridge, 0.2 mile north of loc. 25

27. Along east side of Barge Canal south of Fisk Road
28. Just north of Route 93 and New York Central railroad tracks, on east side of " The Gulf," western outskirts of Lockport
29. Frontier Dolomite quarry, 1.0 mile southwest of Lockport
30. Along Barge Canal for 2 miles southwest of Lockport
30A. Diamond drill core (Bureau of Soils) from hole drilled just off south end of bridge on Transit Road over Tonawanda Creek
31. Across escarpment along Day Road, 0.7 mile east of Lockport
32. Along Rochester Road about 0.5 west of junction with Canal Road
33. Along East Branch of Eighteenmile Creek a few feet north of Mill Road, northeast of Terrys Corner
34. Roadcut over escarpment, directly south of Gasport
35. One-half mile east of loc. 34, where Mountain Road passes over small waterfall
36. One-half mile northeast of loc. 35, along north-south road over escarpment
37. Royalton Stone Corporation quarry at edge of escarpment 1.2 miles east of Gasport

MEDINA

38. Westernmost gully over escarpment 1 mile southwest of Middleport
39. Bank of outlet stream just north of Middleport reservoir
40. Along waterfall in Jeddo Creek where it flows over the escarpment, 1.7 miles west of Shelby
41. Initial excavation for potential quarry southeast of loc. 39, south of Blair Road, 1.3 miles west of Shelby
42. Outcrop in meander cut bank along Whitney Creek, 0.6 mile northwest of Basom
43. Section along Oak Orchard Creek from falls at Shelby south for a distance of about 2 miles
44. Excavation for house on Lewiston Road about 0.5 mile east of four corners in Alabama
45. Outcrop along north-south road between Sanderson Road and Maple Ridge Road
46. Bank of Brinningstool Creek about 0.6 mile south of Wheatville
47. Stream bed just southeast of Millville
48. Roadcut along first road over escarpment east of Millville

49. Diamond drill core, United States Gypsum Company, Oakfield; drilled on eastern margin of Oakfield $7\frac{1}{2}$-minute quadrangle about 0.5 mile south of East Oakfield

ALBION

50. Section over escarpment along second stream from western boundary of quadrangle, 3 miles southwest of Albion
51. Along west branch of Sandy Creek (drainage ditch) south of Lee Road, 0.8 mile east of Route 98 south of Albion
52. Along central branch of Sandy Creek north of bridge on County House Road
53. In stream channel beneath Route 98, 0.3 mile south of South Barre
54. Road ditch on south side of road, 0.25 mile east of four corners at Manning
55. Small outcrop in cornfield on Kennedy farm, about 0.1 mile southeast of loc. 54
56. Abandoned McNall quarry a few feet west of road, 1.1 miles south of Fancher
57. Section at Clarendon Stone Company quarry, southern outskirts of Clarendon west of Route 237
58. Field exposure on O'Brien farm southeast of three corners formed by intersection of LaDue Road and north-south road, about 3.5 miles southeast of Clarendon

BERGEN

59. Roadcut along West Sweden Road over escarpment, 0.4 mile south of Route 31
60. Along north-flowing stream just north of Beadle Road, 0.3 mile east of intersection with Route 19 (Lake Road)
61. Small outcrop along Colby Road, 1.1 miles east of Route 19 (Lake Road)
62. Section along Shumway Road about 0.3–0.4 mile west of intersection with Sweden-Walker Road, about 2 miles south-southeast of Brockport

63. Concrete Materials, Inc. quarry northwest of three corners formed by Sweden-Walker Road and Swamp Road, about 3 miles southeast of Brockport
64. Near top of escarpment along Colby Road, 0.3 mile east of intersection with Sweden-Walker Road
65. Along Salmon Creek just east of Salmon Creek Road bridge
66. Along southwest side of Black Creek, immediately east of tributary junction about 0.85 mile southeast of four corners in Churchville
67. Small outcrops, separated by covered intervals, on slope between Hubbell Road and branch of Salmon Creek, 0.4 mile south of Route 31
68. Along Spring Creek between Brockport Road and Colby Street
69. Farther upstream from loc. 68, along westward-flowing tributary
70. Field exposure 0.1 mile south of Chambers Street, 0.5 mile west of the four corners formed by the intersection of Chambers Street and Adams Basin Road
71. Behind (east) of the old Arnold (presently Smith) farmhouse along the east side of Adams Basin Road, 0.3–0.4 mile south of intersection with Colby Street
72. Small field exposures immediately northeast of four corners south of loc. 71
73. In field a few feet southwest of four corners mentioned at 72 (intersection of Chambers Road and Adams Basin Road)
74. Along southern edge of Colby Street, 0.5 mile east of intersection with Adams Basin Road
75. On slope just north of Stony Point Road, about 0.15 mile east of intersection with Vroom Street
76. Diggings from excavation for waterline along Manitou Road, 0.3–0.4 mile south of Route 31

ROCHESTER

77. In creek bed, 0.2 mile south of Spencerport Road, 0.4 mile east of Elmgrove Road
78. Diggings for sewer line beginning a few hundred feet north of Lyell Road, about 0.5 mile east of Elmgrove Road, and extending north nearly to Spencerport Road
79. Accessible part of sequence exposed along both sides of the Barge Canal about 0.3–0.4 mile east of Long Pond Road

80. Dolomite Products Company quarry southeast of the village of Gates Center
81. Exposures on both sides of the Barge Canal where crossed by Lee Road
82. Canoe traverse along Barge Canal, from a point immediately east of Lee Street bridge southeast to junction of canal and Genesee River
83. Exposures along Mount Read Boulevard between Lexington Avenue and Emerson Street
84. Along west side of Fall Street, 0.25 mile south of western end of Lyell Street bridge over Genesee River
85. Section, mostly inaccessible, on Rochester Gas and Electric Co. property immediately west of upper falls of Genesee River (just north of New York Central Railroad tracks)
86. In bed of Genesee River just north of dam south of Main Street
87. Along Thruway (Route 490) under Penfield Road bridge, Town of Brighton
88. Both sides of Penfield Road beneath railroad overpass, 0.1 mile east of loc. 87
89. Both sides of Route 490, beneath overpass about midway between Linden Road and Penfield Road
90. Along Allen Creek, beginning immediately east of New York Central Railroad overpass and ending about 100 yards south of Westfall Road

MACEDON

91. Small exposure in bed of stream about 0.9 mile south of West Webster
92. Penfield quarry of Dolomite Products Company just north of Whalen Road, 1.0 mile north-northwest of four corners in village of Penfield
93. Excavation for swimming pool, about 100 feet northwest of Atlantic Avenue, 0.3 mile east of Fivemile Line Road
94. Banks of Commission Ditch beneath Harris Road crossing, about 0.5 mile north of East Penfield
95. Drainage ditch beside Salt Road immediately south of Plank Road, about 0.7 mile west of Roseland
96. Small outcrop in drainage ditch a few feet south of Plank Road, 0.25 mile east of County Line Road

97. Small exposure at bend in Mill Creek, 0.13 mile southwest of Swadling Road-Whitney Road intersection
97A. Diamond drill core (owned by Dolomite Products Company, Inc.) from test hole in Town of Walworth, 600 feet west of Tiffany Road, 2,625 feet north of Atlantic Avenue
98. In banks of tributary of Bear Creek west of Ontario Center Road crossing, just north of Paddy Lane
99. Small roadside outcrop immediately north of Plank Road, 0.4 mile east of intersection with Fosdick Road
100. Outcrop just east of Walworth Road, 0.2 mile north of intersection with Morse Hill Road
101. Drainage ditch 0.4 mile north of Trummonds Road and a few feet east of stream west of Trummonds Hill
102. Drainage ditch west of Boyton Hill and about 1.15 miles north of Marion Road
103. Irrigation ditch beneath Town Line Road, 0.15 mile south of intersection with Trummonds Road

PALMYRA

104. Artificial farm pond immediately southeast of Eddy Road-Chapel Road intersection
105. Drainage ditch just south of Route 104, about 1.1 miles west of four corners in Williamson
106. Drainage ditch a few feet north of Ball School Road, 0.2–0.3 mile west of Route 21
107. Exposure in drainage ditch (Red Creek) adjacent to Farnsworth Road crossing, about 0.1 mile east of Route 21
108. Small outcrop in drainage ditch 0.4 mile north-northwest of White Road-Minsteed Road intersection
109. Along creek just west and east of Town Line Road, 1.4 miles south of East Williamson
110. In drainage ditch south of Beam Hill Road, about 0.3 mile northwest of Owls Nest
111. Small outcrop along portion of stream lowered for drainage of muckland, northwest and southeast of Town Line Road intersection with unnamed east-west road, about 1.2 miles north of Owls Nest
112. Small exposure along tributary to Salmon Creek both east and west of Joy Road, about 1.5 miles north of Minsteed Road

113. Diggings from lowering of bed of Salmon Creek and tributary near their point of juncture about 0.3 mile east of loc. 112, 1.4 miles north of Minsteed
114. Along Salmon Creek north and south of Joy Road, about 1.15 miles southwest of Joy
115. Drainage ditch (Salmon Creek) from a point 125 yards east of road (leading north from Joy) southwest for 0.4 mile
116. Small outcrop on west side of Route 88, 0.3 mile north of junction with Felock Road
117. Quarry of General Crushed Stone Company, just south of Quarry Road, about 3.5 miles south-southeast of Sodus
117A. Composite section from two diamond drill cores at General Crushed Stone Company quarry (loc. 117)
118. Exposures along inlet to Metz Pond (Salmon Creek), from Main Barclay Road crossing southwest for about 0.35 mile

CLYDE

119. Along Sodus Creek, beginning a few feet south of bridge on road between North Rose and Glenmark
120. Short sections along each of three small west-flowing tributaries of Sodus Creek within ½ mile south of Briggs Road, southern part of Town of Huron
121. Along stream north of Salter Road, 0.25 mile east of intersection with Fifth Road in North Rose
122. Abandoned quarry (now largely filled with water) east of intersection of Buchanan Road and Limekiln Road, 1.55 miles south-southwest of main four corners in Wolcott
123. Outcrops in and adjacent to Wolcott Creek for about 200 yards south of Smith Road, 2 miles south of the village of Wolcott
124. Small outcrop along drainage ditch on west side of secondary road (Livingston Road) immediately south of stream, 1.9 miles northwest of South Butler and 2.0 miles south-southwest of West Butler
125. Drainage ditch behind Farrow farm on Muckland Avenue about 1.4 miles south of Route 104, about 3.5 miles southeast of Wolcott Village

WEEDSPORT

126. Abandon quarry on west side of Coleman Road, a few feet north of intersection with Moroney Road
127. Small field outcrop along margin of pond just north of Ira Station Road, 0.2 mile west of intersection with Fox Hill Road (marked by sign: " Fox's Kiln ")
128. Outcrop in bed of small stream immediately east of Farnum Road, about 0.55 mile south of intersection with Ira Hill Road

BALDWINSVILLE

129. Excavations for farm pond 100 feet south of Lloyd Road, 0.45 mile east of intersection with Southard Road
130. Abandoned quarry, mostly filled with water, midway between Lloyd Road and Lysander Road, 0.15 mile northeast of loc. 129
131. Small outcrop in abandoned quarry on southwest outskirts of village of Lysander, 0.15 mile south of Lamson Road, 0.35 mile west of Minnetto Lysander Road
132. Abandoned, almost inaccessible quarry a few feet north of Church Road, about 0.1 mile west of intersection with Route 48
133. Abandoned quarry completely overgrown, a few feet west of Route 48, 0.2 mile north of intersection with Church Road
134. Blocks scattered along east side of Seneca River, from 0.5 to about 1.0 mile south of Three Rivers

SYRACUSE

135. Blocks excavated from bed of Oneida River from 0.2–0.3 mile west of southern end of Schroeppel Bridge
136. Abandoned, water-filled quarry in woods 0.1 mile west of Caughdenoy Road, 0.5 mile north of the village of Clay
137. Temporary excavation of North Syracuse school southeast of South Bay Road-Gillette Road intersection
138. Southern Whiting quarry (now inactive and mostly filled with water) in center of triangle bounded by Route 31, South Bay Road, and Whiting Road

139. Small, abandoned quarry immediately west of South Bay Road, 0.15 mile southwest of intersection with Whiting Road
140. Inactive quarry just south of Route 31, 0.4 mile west of eastern margin of quadrangle

CHITTENANGO

141. Layer exposed in bed of Chittenango Creek a few feet south of bridge on Route 31 at Bridgeport (rapids known locally as The Rift)
142. Outcrop and dredgings along Canaseraga Creek beginning about 0.1 mile south of Route 31 and continuing to south for 0.3–0.4 mile, just east of Lakeport's four corners
143. Around margin of farm pond (abandoned quarry of Town of Sullivan) north of road joining Clark Road and Coon Road, about 2 miles east of Lakeport

ONEIDA

144. Abandoned quarry now mostly filled with water, 0.2 mile west of Route 13, about 0.3 mile southwest of Union Corners
145. Scattered exposures east of secondary road, on Faulkner farm, 0.35 mile northwest of Union Corners
146. Small abandoned quarry 0.3 mile southeast of loc. 144, immediately east of Route 13
147. Abandoned quarry just west of paved road about 0.3 mile southeast of Union Corners
148. Farm pond in old quarry located at end of secondary road, 1.2 miles southeast of Union Corners, 0.4 mile north of Thruway
149. Bank of Sconondoa Creek, about 250–300 yards west of Route 365, 0.9 mile east of outskirts of Oneida
150. Outcrops in rapids of Sconondoa Creek a few feet east of Route 365, about 0.15 mile west of four corners in Sconondoa
151. Small exposure in stream bed under Route 365, immediately west of Sconondoa four corners
152. Abandoned quarry 0.1 mile west of Morgan Road, 0.45 mile south-southeast of four corners at Sconondoa

153. Along Sconondoa Creek from William Street in Sherrill westward for about 0.5 mile; also outcrop 100 feet north of bank in small abandoned quarry 0.1 mile west of Elmwood Place
154. Along Sconondoa Creek, beginning just south of Route 5 in Vernon and extending south-southeast to a point 0.2 mile north of Oneida Road

ROME

155. Sporadic, small exposures along tributary of Deans Creek, 0.1–0.2 mile south of Route 5, 2 miles west of Lairdsville
156. Section along creek south of Lairdsville
157. Small creek on College Hill, parallel to and 0.15 mile south of Route 412
158. East-flowing creek on College Hill, about 0.5 mile north of the words "HAMILTON COLLEGE" on the Clinton $7\frac{1}{2}$ minute quadrangle
159. Section exposed continuously for about 0.15 mile along the eastern side of Oriskany Creek, immediately south of the small settlement known as Farmers Mills
160. Sporadic outcrops along Mud Creek from about 820 feet to about 860 feet
161. Outcrops in the stream bed just east of Cleary Road
162. Discontinuous section of Ilion Member in "The Glen," west of Willowvale
163. Section along east-flowing tributary of Sauquoit Creek, about 1 mile south of "The Glen," parallel to and 0.5 mile south of Grange Hill Road

UTICA

164. Along west-flowing tributary of Sauquoit Creek, parallel to and midway between Roberts Road and Laughlin Road
165. Along west-flowing tributary of Starch Factory Creek, 0.7–0.8 mile west of summit of Frankfort Hill
166. South branch of Moyer Creek
167. Isolated ledges on hillside and in small gullies on north side of Joslin Hill

WINFIELD

168. Bed of tributary of Steele Creek, 0.6 mile north of junction of Beckus Gulf road and Route 51, on Hall property
169. Sporadic outcrops in and along Steele Creek, just north of junction of Beckus Gulf road and Route 51
170. Short section along branch of tributary of Steele Creek, about 1.3 miles north of junction of Route 51 and Beckus road
171. In small creek and tributary (creek itself a tributary of Steele Creek) immediately south of Barringer Road, about 0.6 mile southeast of Kinne Corners
172. Very sporadic outcrops along west-flowing tributary of Steele Creek, 0.4–0.5 mile west of North Columbia
173. Section in Spinnerville Gulf from 0.2–0.3 mile west of Spinnerville Gulf Road

RICHFIELD SPRINGS

174. Along Flat Creek both north and south of road
175. Nearly continuous section along stream and dirt road south of small settlement of Deck

Appendix II

DESCRIPTION OF SELECTED SECTIONS

Because a presentation of all 175 sections and outcrops would be impractical, selected sections are chosen for description in the hope that these will offer a representative sample of Lockport stratigraphy. One desiring more information regarding the other outcrops and sections is referred to the writer's Ph.D. dissertation (on microfilm) at Cornell University.

The use of color terms follows the Rock-Color Chart (Goddard, et al., 1951).

Weller (1959, p. 101) stated that many classifications for bedding terminology have been proposed but none have received general acceptance. This writer feels that standardization is not required. Rather, a geologist should select a classification that is best adapted to describing the rocks with which he is working, and then define his terminology. The terminology used for bedding in this report is a modification of that of Dunbar and Rodgers (1957, p. 97):

Table 7. Classification of bedding as used in this report

Thickness	Bedding	Splitting
100+cm.	Very thick-bedded	Thick-parting; massive
30–100 cm.	Thick-bedded	
5–30 cm.	Medium-bedded	Medium-parting; blocky
1–5 cm.	Thin-bedded	Thin-parting; slabby; flaggy
1–cm.	Laminated	Fissile; platy

Splitting and bedding units commonly are indistinguishable in the field. Occasionally, a larger bedding or parting unit includes subordinate laminations. Thus, a description such as " medium-bedded, laminated " is possible.

There also have been numerous proposals for a standardized classification of textures of the sedimentary rocks. Although it is not a purpose of this paper to urge acceptance of any particular system, a few remarks are in order. Textures of chemical rocks, especially dolomites, pose special problems. In this paper, all carbonates are classed in a menner similar to terrigenous clastic rocks (Table 8). Chemical rocks, particularly the carbonates, are either clastic or crystalline. To this writer, it seems incongrous to use an igneous rock grain-size classification for crystalline chemical rocks (as is commonly done and which implies a precipitated origin) but a sedimentary rock grain-size system for clastic chemical rocks. Furthermore, it is not always easy to distinguish between clastic and crystalline chemical rocks in the field. Dolomitization further complicates any inferences as to origin.

Table 8. Classification of sedimentary rocks as used in this report

Grain size	Carbonate textural term	Examples	Terrigenous clastic equivalent
	Coarse grained, or coarse crystalline*	Coarse-grained dolomite; intraformational conglomerate	Conglomerate
2 mm			
	Medium grained, or medium crystalline	Oolite dolomite; medium-grained limestone; dolarenite	Sandstone
.062 mm			
	Fine grained, or fine crystalline	Fine-grained limestone; calcilutite	Siltstone
.016 mm			
	Very fine grained; aphanitic; microcrystalline	Very fine-grained dolomite; micrite	Mudstone
.004 mm			
	Dense; cryptocrystalline	Dense limestone; micrite	Shale, claystone

* " crystalline " is used as descriptive term only

The term " crinoidal " in this paper includes fragments of other pelmatozoans. Many of the so-called crinoidal fragments are in reality pieces of crystoids.

There follow descriptions of the selected sections in various 15-minute quadrangles.

1. Across Niagara Escarpment along Lewiston Road south of Lewiston; Niagara Falls quadrangle. (See also Figure 29.)

	Feet
Lockport Formation	
Goat Island Member	
4 Dolomite, light olive-gray, medium- to thick-bedded, medium-grained; subconchoidal fracture; disseminated white chert nodules[8]	4.0
Gasport Member	
3 Limestone, brownish-gray to medium-gray, medium-bedded, coarse-grained, fossil-fragmental; weathers olive-gray; very fossiliferous, including brachiopods, bryozoans, and crinoidal debris; most crinoidal in lower and upper parts; middle part biostromal; base of Gasport at about 565 feet	15.0
DeCew Member	
2 Dolomite, medium-gray, thin-bedded to massive, fine- to medium-grained, argillaceous; upper part contains "enterolithic" structure; light-green just below corrosion surface marking contact with overlying Gasport; lower part not well exposed, grades upward from underlying Rochester shale	8.0
Total thickness of Lockport Formation.........	27.0

Rochester Shale

Outcrops of Rochester shale, separated by covered intervals, occur below

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2. Continuous exposure along the south haul road leading from the Niagara Power Project generating plant 1.7 miles south of Lewiston; Niagara Falls quadrangle

Lockport Formation

Eramosa Member

11 Dolomite, dark-gray, medium-bedded, fine-grained, argillaceous; weathers distinct light-gray; bituminous; carbonaceous shaly partings;

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[8] Numbers refer to field units.

	vugs containing dogtooth spar and gypsum; sphalerite in massive bed at base; galena in upper part, fossils poorly preserved, include brachiopods and cephalopods, such as *Atrypa, Stegerhynchus, Dawsonoceras,* and *Lechritochoceras*	18.0
10	Dolomite, medium dark-gray to brownish-gray, blocky, stylolitic, medium-grained, saccharoidal; slight bituminous odor; vugs containing dolomite rhombs; fossiliferous, mainly corals including *Favosites* and *Enterolasma;* fretted white chert pods with fossil fragments including *Calymene, Dalmanites,* and *Platyceras;* separated from overlying unit by ½ inch zone of shaly-bedded dolomite	2.0
	Total thickness of Eramosa Member	20.0

Goat Island Member

9	Dolomite, light olive-gray to light brownish-gray, very thick-bedded, massive, medium-crystalline; shally partings; microstylolites; white chert nodules near top; basal 5 feet slightly coarser and more porous; relatively unfossiliferous, fragment of *Protomegastrophia* noted; shaly, limonitic parting marks contact with overlying unit	17.5
8	Dolomite, dark-gray, medium-grained; vugs containing massive gypsum, druse of dogtooth calcite; gradational into overlying	1.5
	Total thickness of Goat Island Member	19.0

Gasport Member

7	Dolomite, brownish-gray to olive-gray, medium-bedded, medium-grained, calcareous; shaly partings; vugs containing sphalerite and gypsum; fossils include stromatoporoids, *Favosites, Enterolasma,* and sporadic crinoidal fragments	9.0
6	Dolomite, medium-bedded, medium-grained, calcareous; crinoidal	2.0
5	Dolomite, medium-gray to medium dark-gray, medium-grained, calcareous; weathers light olive-gray; vuggy; gypsiferous; darker stringers generally parallel to bedding	3.0

4 Dolomite, medium dark-gray, thin- to medium-bedded, medium-grained; stylolitic; vuggy; crinoidal; dolomitized fossil fragments (reef detritus?); intercalated shaly-bedded layers.. 1.5

3 Dolomite, olive-gray to brownish-gray, thick-bedded, massive, coarse-grained, fossil-fragmental; crinoidal; weathers lighter than underlying DeCew; dark laminations; stylolites; basal contact distinct 7.0

Total thickness of Gasport Member............ 22.5

DeCew Member

2 Dolomite, medium-gray, massive, fine-grained, argillaceous; green immediately below abrupt contact with Gasport (contact marked by corrosion surface covered with black, argillaceous material) 8.0

Total thickness of Lockport Formation.......... 69.5

Rochester Shale

1 Shale, gray, thin to shaly-bedded, dolomitic; sharp contact with DeCew at 496 feet

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4. Along ramp leading into work area No. 2 immediately south of railroad crossing, Niagara Power Project; Niagara Falls quadrangle

Lockport Dolomite

Oak Orchard Member

8 Dolomite, brownish-gray to dark-gray, medium-crystalline, thick-bedded, massive, saccharoidal, bituminous; slightly porous; vugs present but not common; minerals, such as anhydrite, sphalerite, fluorite, and galena, in vugs and veinlets; one poorly preserved specimen of *Favosites*... 8.0

7 Dolomite, fine- to medium-grained, thin-bedded to massive; transitional between units 6 and 8 2.0

6 Dolomite, dark-gray to brownish-gray, medium-crystalline, thin-bedded to massive, calcareous and bituminous; stromatolitic; large vugs in massive portions; minerals include galena, calcite, and sphalerite........................ 21.8

5 Dolomite, medium dark-gray to brownish-gray, medium-crystalline, medium-bedded to massive, slightly calcareous; bituminous; dark carbonaceous stringers; brownish-gray porous zones....	18.8
4 Dolomite, dark-gray to brownish-gray, fine- to medium-grained, thin- to medium-bedded; numerous vugs, especially near base; anhydrite and selenite in vugs; poorly preserved, dolomitized specimens of *Favosites*	5.8
Total thickness of Oak Orchard Member........	56.4
Eramosa Member	
3 Dolomite, medium- to dark-gray, fine-grained, thin- to medium-bedded, argillaceous, bituminous; slightly coarser-grained at base becomes more thinly bedded, more argillaceous, and less vuggy from base upward; upper part weathers distinct light gray; *Dawsonoceras*...........	18.0
Goat Island Member	
2 Dolomite, light brownish-gray to medium light-gray, medium-grained; carbonaceous partings; white chert nodules.........................	7.0
1 Dolomite, medium-gray to brownish-gray, medium- to thick-bedded; stylolites; shaly partings; vugs numerous in middle part, contain gypsum, sphalerite, and corals..............	9.0
Total thickness of Goat Island Member........	16.0
Total thickness of Lockport Formation.........	90.4

Note: Base of measured section at about 500 feet

7. Intake area on Niagara River, Niagara Power Project; Niagara Falls quadrangle

Lockport Formation	
Oak Orchard Member	
6 Dolomite, dark brownish-gray, medium-grained, thin- to medium- and even-bedded; selenite and snowy gypsum; dolomitized pelecypods (*Pterinea*?)	4.0

5	Dolomite, brownish-gray to medium dark-gray, medium-grained, argillaceous; bedding varies from shaly to thin to medium; shaly seams and partings; oolitic texture especially prominent near base; slickensides on some shaly surfaces of curved plates from stromatolites; galena and gypsum	8.0
4	Dolomite, medium dark-gray to brownish-gray, medium-grained, medium-bedded; bituminous	2.5
3	Dolomite, fine-grained, nonresistant; forms reentrant; sphalerite and fluorite; slightly bituminous	0.1
2	Dolomite, medium dark-gray to brownish-gray, medium-crystalline, calcareous; lower part has oolitic texture and layers of coarser intraformational conglomerate; leperditiids in upper part	1.0
1	Dolomite, medium dark-gray to brownish-gray, medium-crystalline, medium-bedded, laminated; carbonaceous seams; microstylolitic; sphalerite; fragment of orthocone	6.5
	Total thickness of Oak Orchard Member	22.1

Base of measured section at about 545 feet

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9. Niagara Stone Company quarry, 0.3 mile north of Lockport Road, 1.9 miles east of Pletchers Corners; Tonawanda quadrangle

Lockport Formation

Oak Orchard Member

4	Dolomite, brownish-gray to dark-gray, medium-grained, saccharoidal, massive, bituminous; profusion of *Favosites,* biostromal; cup corals; numerous, large vugs containing pale-yellow calcite crystals; three other local facies within this interval	20.25
	(a) brown, laminated, porous, stylolitic dolomite with sporadic specimens of *Favosites;* vugs containing calcite and purple fluorite; in places stromatolites as in underlying unit (3)	

(b) medium-gray to brownish-gray intraformational conglomerate; fine-grained dolomite fragments in crystalline matrix	
(c) dark-gray to brownish-black, thin- to medium-bedded dolomite; bituminous; shaly seams and partings	
3 Dolomite, brownish-gray to dark-gray, medium-grained, saccharoidal; massive, stromatolites averaging 4–5 feet across (some over 10 feet), associated with thinner bedded, argillaceous dolomite which wraps around the structures; bituminous; stylolitic; contact with overlying unit commonly abrupt, undulating; in places, however, stromatolites extend up into unit 4	25.0±
2 Dolomite, brownish-gray, medium-crystalline, thick-bedded, massive, saccharoidal; lower 6 feet extremely vuggy; dark carbonaceous stringers in upper part; microstylolites; bituminous; shaly partings; minerals include calcite, sphalerite; and fluorite	16.5
Total thickness of Oak Orchard Member	65.0±
Eramosa Member	
1 Dolomite, dark-gray to brownish-black, fine-grained, thin- to medium- and even-bedded, argillaceous; weathers distinct light-gray; bituminous; carbonaceous, black, shaly partings on bedding surfaces; scattered vugs containing gypsum; specimen of *Dawsonoceras*; sharp contact with overlying unit	12.0
Total thickness of Lockport Formation	77.0±

Quarry floor at elevation of about 550 feet

14. Section below overhead along Route 429, northern part of Pekin, Tonawanda quadrangle

Lockport Formation	
Goat Island Member	
3 Dolomite, medium- and even-bedded; weathers lighter than below; lower contact undulating . .	2.0±

Gasport Member

2 Limestone, light brownish-gray, medium- to irregularly- bedded, medium- to coarse-grained, fossil-fragmental; above lower 2.5 feet is small bioherm consisting of light-gray, fine-grained, structureless, argillaceous limestone; associated with bioherm are light olive-gray to brownish-gray, finely crystalline, porous calcareous dolomites; crinoidal throughout but fragments most abundant in lower 2.5 feet with *Atrypa;* bioherm abundantly fossiliferous, corals and stromatoporoids predominate, including *Heliolites, Cystiphyllum*	20.0±

DeCew Member

1 Dolomite, light olive-gray, fine-grained, thick-bedded, argillaceous; cross laminations on weathered surfaces; microstylolites; zones of intraformational conglomerate; intercalations of coarser, crinoidal dolomite (resembling Gasport lithology) containing pebbles of DeCew-like lithology; *Atrypa* and *Whitfieldella* (?) in upper part; greenish just below abrupt contact with Gasport proper at elevation slightly above 600 feet	5.5
Total thickness of Lockport Formation..........	28.0±

Note: Section begins in DeCew

23. Roadcut across escarpment, 0.5 mile south of Hickory Corners (Route 270); Tonawanda quadrangle

Lockport Formation

Gasport Member

4 Limestone, light bluish-gray to medium-gray, medium- to coarse-grained, medium-bedded, fossil-fragmental, crinoidal; joints; extremely fossiliferous, predominantly brachiopods, also bryozoans, stromatoporoids, corals; *Whitfieldella, Atrypa, Stegerhynchus, Eospirifer, Rhynchotreta,* and others; noncrinoidal, friable

	dolomite layers in upper part; uppermost bed is thick, vuggy	22.0
DeCew Member		
3	Dolomite, medium light-gray, fine- to medium-grained, medium-bedded, laminated, argillaceous; cross laminations show on weathered surfaces; "enterolithic" structure; greenish just below abrupt upper contact with Gasport	6.5
2	Dolomite, medium light-gray, thin-bedded, fine-grained; weathers to shaly parting; unfossiliferous	5.0
	Total thickness of DeCew Member	11.5
	Total thickness of Lockport Formation	33.5
Rochester Shale		
1	Shale, dolomite; weathers dark gray; thin beds of argillaceous dolomite; grades into overlying	3.5

29. Frontier Dolomite quarry, 1.0 mile southwest of Lockport; Lockport quadrangle

Lockport Formation		
Goat Island Member		
9	Dolomite, medium-grained, medium-bedded, saccharoidal; shaly seams and partings; finer-grained and thinner-bedded toward top; scattered brachiopod and trilobite fragments	12.0
8	Dolomite, dark-gray to brownish-gray, medium-bedded; dolomitized fossil detritus including stromatoporoids; selenite; bed probably represents reef detritus	2.0
7	Dolomite, medium-grained, saccharoidal, massive; porous; very vuggy; stylolites; calcite crystals and dolomite rhombs; numerous stromatoporoids (biostromal?) replaced by yellowish-gray, friable dolomite; crinoid fragments in lower part; grades into overlying	5.5
6	Dolomite, distinct yellowish-gray to light olive-gray, blocky, medium-grained, saccharoidal; carbonaceous stringers; small vugs containing	

dolomite rhombs; grades into overlying	2.5
5 Dolomite, dark-gray, fine-grained, weathers lighter gray	2.0
Total thickness of Goat Island Member	24.0
Gasport Member	
4 Dolomite, medium dark-gray, fine-grained, medium- and even-bedded, argillaceous; vugs with gypsum; sphalerite, galena, calcite; fossils include *Leptaena, Atrypa, Halysites, Dawsonoceras,* dendroid; two other facies within this interval: (a) structureless dolomitized bioherms; medium light-gray, fine-grained to very fine-grained; some crinoid fragments; small dolomitized pods probably represent fossils (b) dark-gray to medium bluish-gray, vuggy dolomite; reef detritus(?) consisting of stromatoporoids and other debris which grades laterally to bioherms in one direction and to main part of unit 4 in the other	15.5
3 Limestone, medium light-gray to light bluish-gray, coarse-grained, massive, crinoidal; upper part more porous and dolomitic; lower 12 feet fossiliferous; upper 2 feet transitional to overlying unit; lower contact undulating	14.0
Total thickness of Gasport Member	29.5
DeCew Member	
2 Dolomite, brownish-gray to medium dark-gray, fine-grained, massive, argillaceous; intraformational conglomerate near base; "enterolithic" structure pronounced; gypsum; upper 6 inches fossiliferous including *Atrypa;* greenish zone just under abrupt contact with Gasport	3.5
1 Dolomite, medium-gray, fine-grained, laminated; slightly contorted	5.0
Total thickness of DeCew Member	8.5
Total thickness of Lockport Formation	62.0

Back of section (quarry floor) at elevation of about 530 feet

37. Royalton Stone Corporation quarry at edge of escarpment 1.2 miles east of Gasport; Lockport quadrangle

Lockport Formation	
Gasport Member	
6 Dolomite, light bluish-gray, medium- to thick-bedded, fossil-fragmental, crinoidal, coarse-grained, calcareous; basal 2–3 feet darker gray, becoming more porous and stylolitic upward; fossils include *Leptaena, Eospirifer, Whitfieldella, Stegerhynchus, Fenestrellina;* bioherms in lowest part of interval; very poorly preserved corals and stromatoporoids; in some places, e.g., east face, entire sequence marked by undulating bedding — here a stromatoporoidal dolomite containing *Cladopora*(?); another facies represented in southeast face by 10–12 feet of dark, argillaceous dolomite in upper part of interval; upper part of the Gasport at eastern end becomes biostromal, containing corals, such as *Favosites, Cystophyllum, Cladopora,* and *Halysites,* and profusion of stromatoporoids	30.0±
DeCew Member	
5 Dolomite, fine-grained, light-green pebbles; fossiliferous including *Fardenia* and *Atrypa;* scattered crinoid columnals; transitional to Gasport	0.5–1.0
4 Dolomite, medium dark-gray to brownish-gray, fine-grained, thin- to medium-bedded; middle part laminated; zones of intraformational conglomerate; intercalated dolomitic shales; *Buthotrephis*	8.5
Total thickness of DeCew Member	9.0±
Total thickness of Lockport Formation	39.0±
Rochester Shale	
3 Shale, earthy, fissile to platy; weathers lighter gray	2.0
2 Dolomite, brownish-gray, thin-bedded	0.5
1 Shale, brown thin-bedded to shaly-bedded, dolomitic	1.0

Note: DeCew and Rochester observed along entrance road; base of section about 595 feet

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43. Section along Oak Orchard Creek from falls at Shelby south for a distance of about 2 miles; Medina quadrangle

Lockport Formation

Oak Orchard Member

12	Dolomite, dark-gray to brownish-gray, medium-crystalline, medium- and uneven-bedded; porous; brownish-gray zones; carbonaceous stringers; sphalerite and dolomite in veinlets; microstylolites; nodules of white chert near base; dolomitized, poorly preserved specimens of *Favosites, Enterolasma* (?); stromatoporoids; this is horizon of upper Guelph fauna (Upper Shelby) of Clarke and Ruedemann and is southernmost unit exposed in this section	4.5±
11	Covered; southernmost exposure of unit 10 is under Route 63; northernmost outcrop of unit 12 is about 0.1 mile southwest of this point	2.0±
10	Dolomite, dark-gray to brownish-gray, medium-crystalline, medium- and uneven-bedded; carbonaceous stringers; styloites; elongate whitish chert nodules parallel to bedding (no fossils noted in chert); grades upward into slightly darker, coarser dolomite with brownish-gray, porous zones as in unit 12; fossils rare, poorly preserved, include stromatoporoids, *Enterolasma, Halysites,* and *Cladopora;* galena throughout unit, sphalerite; small vugs, slightly bituminous	7.0±
9	Dolomite, medium-gray to grayish-red, thin-splitting to massive, fossil-fragmental, medium to coarse-grained; intercalated finer-grained dolomite; galena; fossiliferous, especially corals — *Zaphrentis, Enterolasma, Cladopora,* and *Favosites*; reddish color apparently due to hematite content	3.5
	Total thickness of Oak Orchard Member	17.0±

Goat Island Member		
8	Dolomite, brownish-gray to darker-gray, medium-grained, thin- to medium-bedded; bedding surfaces commonly uneven and in places fretted; stylolites; sphalerite, dolomite rhombs; leading faunal element is *Enterolasma;* also *Leptaena, Whitfieldella, Stegerhynchus,* and *Protomegastrophia;* within this interval is horizon of lower Guelph fauna of Clarke and Ruedemann	7.0
7	Covered	2.0
6	Dolomite, brownish-gray to dark-gray, medium-grained, thin- to medium-bedded; fossils rare, include *Enterolasma*; like unit 8 and probably continuous with it under cover	2.5
Goat Island-Gasport Members		
5	Covered; northernmost exposures of unit 6 occur about 0.4 mile north of Harrison Road bridge; near this point, rock piles on banks show preponderance of light olive-gray, crinoidal, calcareous dolomite — the characteristic Gasport lithology; also *Atrypa, Halysites;* Gasport-Goat Island contact within covered interval, probably near top, stratigraphically	15.0±
Gasport Member		
4	Dolomite, light olive-gray, porous, irregularly bedded; exposure just north of dam at Shelby	1.5
DeCew Member		
3	Dolomite, medium-gray to brownish-gray, fine- to medium-grained, thin- to medium-bedded, argillaceous; laminated; weathers yellowish-gray to light olive-gray; undulating bedding in upper part; intercalated gray shales and thin, coarser-grained layers of crinoidal dolomite; upper part of unit caps the falls at Shelby	13.0
2	Shale, dolomitic; intercalated medium-bedded, argillaceous dolomite; within dolomite layers are coarser-grained, calcareous, crinoidal zones	5.0
	Total thickness of DeCew Member	18.0
	Total thickness of Lockport Formation	63.0±

Rochester Shale

1 Shale, brownish-gray 3.0

Note: Based on measured section at bottom of falls at Shelby

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57. Section at Clarendon Stone Company quarry, southern outskirts of Clarendon west of Route 237; Albion quadrangle

Lockport Formation

Goat Island Member (in zone of eastward transition to Penfield Member)

6 Dolomite, olive-gray to brownish-gray, crystalline, medium- and even-bedded; becomes slightly darker and coarser upward; whitish chert nodules especially abundant in lower 6–7 feet; upper part has intercalated layers of crinoidal, calcareous dolomite; *Enterolasma* and *Protomegastrophia;* sphalerite 25.0

Gasport Member

5 Dolomite, brown, medium- to coarse-grained, medium-bedded, crinoidal; basal portion has argillaceous stringers and laminations similar to those seen in DeCew; other facies related to this general sequence:

(a) small bioherm of light-gray weathering, very fine-grained dolomite (seen in west wall)

(b) flank beds of dark-gray dolomite with abundant fossil detritus including stromatoporoids, corals; vugs with gypsum, dolomite rhombs, and sphalerite

(c) argillaceous dolomite layers; crinoidal; grade laterally into flank beds of bioherm 13.0

Note: Typical Gasport lithology, a crinoidal dolomite, seen in north face where unit becomes more porous and grades upward into a very thick, porous, vuggy, biostromal bed containing abundant *Favosites* and stromatoporoids

DeCew Member

4 Dolomite, medium-gray, laminated, fine-grained, argillaceous; intercalated shales in lower part; crinoidal detritus just below contact with Gasport; *Atrypa*.	2.0
3 Dolomite and dolomitic limestone, medium-gray, fine-grained, argillaceous, medium- to irregularly bedded; laminated layers; crinoidal layers	8.5
2 Dolomite, medium-gray, fine-grained, argillaceous; weathers light-gray; "enterolithic" structure; carbonaceous shaly partings; bed continuous around lower part of quarry.	2.5
Total thickness of DeCew Member.	13.0
Total thickness of Lockport Formation.	51.0

Rochester Shale (transitional to DeCew)

1 Shale, dolomitic; alternating with thin-bedded, fine-grained, argillaceous dolomite; uppermost 6 inches consist of dolomitic shale; true Rochester exposed below along entrance road.	4.0

Note: Section dips to west at 5°; top of quarry at about 660 feet

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63. Concrete Materials, Inc. quarry northwest of three corners formed by Sweden Walker Road and Swamp Road, about 3 miles southeast of Brockport; Bergen quadrangle

Lockport Formation

Limestone "lentil"

5 Limestone, medium dark-gray, fine-grained, medium-bedded; basal 3 feet laminated; shaly partings; fossiliferous, including *Stegerhynchus, Strophonella, Dalmanites, Trimerus,* and *Homalonotus*; interbedded thin layers of fossil fragments (brachiopods and trilobites); also layers of coarse-grained, crinoidal limestone resembling Gasport lithology; thin zones of intraformational conglomerate; uppermost part has thinner bedding, gastropods.	17.0

4 Limestone, medium dark-gray, fine-grained; irregularly bedded, contorted; pebbles of DeCew lithology in basal part; oxidized zone marks base of unit at eastern end of quarry; at western end, shale parting and clay generally at base but in places limestone extends below; brachiopod and trilobite fragments; crinoidal layers; grades into overlying	4.2
Total thickness of limestone "lentil"	21.2
DeCew Member	
3 Dolomite, massive, contorted, fine-grained, argillaceous; more calcareous upward; sharp, uneven contact with overlying	2.0
2 Limestone, medium dark-gray, fine-grained, irregularly bedded; vugs containing anhydrite; carbonaceous shaly partings; fossils including *Stegerhynchus;* changes laterally into less calcareous beds	5.0
1 Dolomite, light-gray, fine-grained, thick-bedded, "enterolithic" structure; changes laterally to thinner-bedded intervals	4.0
Total thickness of DeCew Member	11.0
Total thickness of Lockport Formation	32.2

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80. Dolomite Products Company quarry just southeast of the village of Gates Center; Rochester quadrangle

Lockport Formation	
Oak Orchard Member	
8 Dolomite, brownish-gray to brownish-black, medium-crystalline, saccharoidal, medium- and uneven-bedded; distinctly thinner-bedded than underlying unit; weathers light olive-gray to yellowish-gray; fossils, including *Enterolasma,* coated with small siliceous nodules; stylolitic	18.0
Penfield Member	
7 Dolomite, brownish-gray to dark-gray, saccharoidal, medium- to thick-bedded, quartzose;	

	biostromal layers have vermicular appearance on weathered surface; some beds slightly calcareous; fossils include *Cystiphyllum Zaphrentis*(?), *Cladopora, Enterolasma, Strophonella, Protomegastrophia, Dawsonoceras,* stromatoporoids, and crinoid fragments; numerous vugs containing gypsum, sphalerite, and dolomite; some beds have brownish-black shaly partings; sporadic bituminous beds; unit transitional between Penfield and Oak Orchard members....	17.0
6	Dolomite, brownish-gray to medium dark-gray, saccharoidal, porous; weathers dark-brown; easily traced across quarry wall; sharp, uneven, lower and upper contacts; *Enterolasma* most abundant fossil; little pockets with profusion of *Cladopora;* crinoid fragments; vugs containing dolomite, sphalerite, snowy gypsum, and selenite	1.7
5	Dolomite, medium dark-gray to dark brownish-gray, saccharoidal, medium- to thick- and even-bedded, quartzose; carbonaceous shaly partings; dolomite rhombs, sphalerite............	11.8
4	Dolomite, brownish-gray to medium dark-gray, medium grained, saccharoidal, thin- to medium-bedded, quartzose; abundant brownish shaly partings in some layers producing shaly-bedded effect; intercalated thicker, laminated layers with no partings; crinoidal layers; gypsum; weathers olive-gray	16.7
3	Dolomite, medium light-gray to medium-gray, medium-grained, medium- to thick-bedded, very quartzose; cross-laminated; shaly partings; strong petroliferous odor..................	4.8
Total thickness Penfield Member.............		52.0
DeCew Member		
2	Dolomite, medium-gray to medium dark-gray to brownish-gray, medium-grained, medium- to thick and irregularly bedded, siliceous; "enterolithic" structure; vugs containing gypsum; upper part bituminous; grades upward into Penfield Member	12.0
Total thickness of Lockport Formation.......		82.0

Rochester Shale

Gates Member

1 Dolomite, dark-gray to brownish-black, fine-grained, thin- to medium-bedded, argillaceous, siliceous; weathers light olive-gray; vugs containing gypsum; sporadic crinoid rhombs; bituminous near base; minor intercalated layers of dark dolomitic shales; undulating contact with overlying " enterolithic " DeCew............. 18.0

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90. Along Allen Creek beginning immediately east of New York Central overpass and ending about 100 yards south of Westfall Road; Rochester quadrangle

Salina Group

Vernon Shale (?)

19 Shales and mudstones, light olive-gray to grayish-olive, thin-bedded and platy to thinly laminated; thin, dark brownish-gray dolomitic beds with greenish-gray laminae; 6-inch reddish mudstone bed near top..................... 7.0

Lockport Formation

Oak Orchard Member

18 Covered interval to point just south of Westfall Road; some of interval may be equivalent to Salina 5.0

17 Dolomite, brownish-gray, medium-grained, thin- to medium-bedded; stromatolitic............. 1.0

16 Covered to point midway between Edgewood Road and Westfall Road.................. 20.0

15 Dolomite, brownish-gray to dark-gray, medium-grained, medium-bedded; stromatolitic; thin, platy beds; intraformational conglomerates; upper bed massive, bituminous; fossils include *Favosites,* fucoids, and unidentified spiriferid brachiopod 17.0

14 Covered to point about halfway between Allendale School and Clover Road................ 5.0

13 Dolomite, brownish-gray, medium- to fairly even-bedded 2.0

12	Dolomite, brownish-gray to dark-gray; massive, irregularly bedded, stromatolitic; very vuggy; dolomite rhombs in some vugs; pockets of sandy-textured dolomite	7.0
11	Dolomite, dark-gray, medium-crystalline, medium- and even-bedded; brownish-gray pockets and lenses	3.0
10	Covered interval from unit 9 to just north of Allendale School	35.0
9	Dolomite, dark-gray to brownish-gray to brownish-black, medium-bedded; porous; vuggy; stromatoporoids poorly preserved in lighter-colored dolomite	2.0
8	Covered to point 60 yards southwest of East Avenue where small falls exposes Lockport	2.5
	Total thickness Oak Orchard Member	98.0±
	Penfield Member	
7	Dolomite, medium-gray to brownish-gray, saccharoidal, medium-bedded; brownish-gray patches; crinoidal layers of darker dolomite, slightly coarser-grained and bituminous	10.8
6	Covered to just north of Linden St. bridge	1.5
5	Dolomite, medium-grained, medium-bedded, quartzose; very crinoidal; porous; vuggy	2.0
4	Covered from west end of railroad bridge to west side of Route 490	15.0
3	Dolomite, medium dark-gray to brownish-gray, medium-grained, saccharoidal, quartzose, medium-bedded; sporadic brownish-gray lenses; crinoid stems abundant in some layers	16.5
2	Covered	1.0
1	Sandstone, medium-gray to medium light-gray, medium-grained, medium-bedded, dolomitic; laminated in lower part; beds with numerous thin, wavy shaly seams; microstylolities	7.9
	Total thickness Penfield Member	54.0±
	Total thickness Lockport Formation	152.0±

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92. Penfield quarry of Dolomite Products Company, just north of Whalen Road, 1.0 north-northwest of four corners in village of Penfield; Macedon quadrangle

Lockport Formation

Oak Orchard Member

16	Dolomite, dark-gray to brownish-gray, medium-grained, massive, fossiliferous and vuggy; biostromal and very similar in faunal and mineral content to unit 12	3.0±
15	Dolomite, olive-gray to brownish-gray, medium-bedded, fossiliferous; persistent band around second level of quarry; includes *Favosites, Zaphrentis, Howellella, Herrmannina*	1.3
14	Dolomite, brownish-black, massive, bituminous; gradational into overlying unit	3.0±
13	Dolomite, light brownish-gray to brownish-gray, medium-crystalline, massive; numerous parallel stylolites; sparsely fossiliferous; stylolitic contact with underlying biostromal unit; bed persistent around quarry but thickest at north end	1.5–3.0
12	Dolomite, dark-gray to brownish-black, saccharoidal, massive; bituminous; carbonaceous shaly partings and undulating stringers; weathers darker than above; lighter colored sandy textured pockets; biostromal with stromatoporoids the main element; also *Favosites, Halysites,* and *Cladopora;* vugs containing a variety of minerals, such as fluorite, dolomite, calcite, celestite, galena, gypsum, selenite, pyrite, marcasite, sphalerite, and others; some silicification of fossils	3.0
11	Dolomite, brownish-gray to medium dark-gray, medium-crystalline, thick-bedded, massive; upper 3 feet has brownish-gray patches; sporadic vugs near top; contact with overlying biostrome along stylolite or corrosion surface covered with carbonaceous material	4.1
	Total thickness of Oak Orchard Member	17.0±

Penfield Member

10	Dolomite, dark-gray to brownish-gray, medium-grained (finer-grained than 9), medium-bedded; slightly quartzose; wavy carbonaceous stringers; weathers distinct light olive-gray to yellowish-gray in upper part; sphalerite	1.6

9	Dolomite, medium dark-gray with light-gray to brownish-gray patches and bands (½ inch to laminae), medium-grained, saccharoidal, medium-bedded, siliceous; sandy texture; sphalerite; sporadic vugs containing dolomite rhombs; separated abruptly and stylolitically from overlying unit	11.0
8	Dolomite, medium dark-gray, medium-grained, medium-bedded, saccharoidal; brownish-gray pods; crinoid "rhombs"; stylolites; carbonaceous shaly partings; slightly quartzose; vugs; lower contact marked by corrosion surface; reentrant marks upper contact	1.4
7	Dolomite, dark-gray to brownish-gray, medium-crystalline (coarser than underlying), medium- to thick-bedded, quartzose; undulating black carbonaceous partings fairly evenly spaced, about 2 inches apart; laminated and slightly coarser and sandy texture toward top	10.5
6	Dolomite, medium dark-gray, fine-grained, thick-bedded, massive, quartzose; thin, black, wavy stringers	5.5
5	Dolomite, brownish-gray to medium dark-gray, medium-grained, thick-bedded, massive, quartzose; brownish-gray, elongate pods; sporadic crinoid "rhombs"; unit is at top of lower level of quarry	3.0±
4	Dolomite, medium light-gray to medium-gray, saccharoidal, sandy-textured, medium- to thick-bedded, siliceous; laminated toward top	6.5
3	Dolomite, medium dark-gray to dark-gray, medium-grained, thick-bedded, and cross-laminated; very slightly siliceous; darker in color and weathers darker brown than underlying and overlying units; gypsum	8.3
2	Dolomite, medium light-gray, medium-grained, medium- to thick-bedded, very quartzose; nonlaminated except near top; thin carbonaceous seams randomly oriented; persistent shaly parting 3.5 feet above base; upper contact sharp, uneven	7.2
1	Sandstone, medium light-gray to medium-gray, medium-grained, medium- to thick-bedded,	

	dolomitic; some thinner beds; cross-stratified and cross-laminated; microstylolites	8.0
	Total thickness of Penfield Member	62.7±
	Total thickness of Lockport Formation	79.7±

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117. Quarry of General Crushed Stone Company, immediately south of Quarry Road, about 3.5 miles south-southeast of Sodus; Palmyra quadrangle

Lockport Formation

Oak Orchard Member

10	Dolomite, brownish-gray to grayish-black, medium-grained, medium-bedded, bituminous; carbonaceous shaly coatings on bedding surfaces; *Favosites* common 5 feet from top; friable layers; current ripple marks; yellowish calcite on some fracture and bedding surface	12.7
9	Dolomite, dark brownish-gray, medium-grained, medium- and even-bedded; friable; banded to laminated; intercalated brownish-gray, flaggy layers; a pelecypod (*Pterinea*)	5.0
8	Dolomite, dark-gray to brownish-gray, medium-bedded, bituminous, fossiliferous; carbonaceous partings; sphalerite; fossils include *Favosite, Cladopora,* and stromatoporoids (?); at top is 3-inch layer of silt and clay	2.0
7	Dolomite, brownish-gray to dark-gray, medium-grained, medium-bedded, bituminous; lighter brown, porous zones; brownish-black, sandy-textured layers; sphalerite; small, poorly preserved bryozoans near top	4.0
6	Dolomite, brownish-gray to brownish-black, medium-crystalline, thick-bedded, massive, bituminous; medium-bedded layers at bottom and top; porous beds having sandy texture; separated from overlying by ½-inch silt band	7.1
5	Dolomite, brownish-black, saccharoidal, thick-bedded, massive, sandy-textured, porous, bituminous	3.5
4	Dolomite, dark brownish-gray to grayish-black, medium-grained (coarser than underlying and	

	overlying units), medium-bedded to thin-bedded, bituminous; laminations of friable, porous dolomite possessing sandy texture; zones of intraformational conglomerate	8.5
3	Dolomite, similar to underlying unit but weathers brown; medium- to thick-bedded; laminated and cross-laminated; stylolites; coarser layers	9.0
2	Dolomite, brownish-black to dark-gray, saccharoidal, thick-bedded, massive; weathers olive-gray; lower part largely covered with talus, thinner-bedded; upper contact sharp, stylolitic	7.7
1	Dolomite, dark-gray to brownish-gray, medium-grained, medium- and even-bedded, bituminous	5.0±
	Total thickness of Lockport Formation (Oak Orchard Member)	64.5

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153. Along Sconondoa Creek from William Street in Sherrill westward for about 0.5 mile; also outcrop just north of bank in small abandoned quarry 0.1 mile west of Elmwood Place; Oneida quadrangle

Lockport Formation

Sconondoa Member in area of transition eastward to Ilion Shale

6	Dolomite, grayish-black to dark-gray, medium-grained, sparkling, sandy-textured, thin- to medium-bedded; basal layers even-bedded to flaggy, laminated; one uneven bed of vuggy, porous dolomite containing profusion of *Howellella* and brown, sandy pebbles; uppermost layers are finer-grained, argillaceous, shaly- to medium-bedded; unit referred to dolomite facies	3.0
5	Limestone, dark-gray to grayish-black, fine-grained to aphanitic, shaly- to thick-bedded, argillaceous; thick, stromatolitic bed in middle of unit; upper layers consist of limestone containing small and larger ostracodes (leperditiids); limestone facies; units 5 and 6 in abandoned quarry mentioned above	2.5

4	Covered	2.0–3.0
3	Limestone, dark-gray, fine-grained, medium-bedded; thin shaly partings; cross laminations; ostracodes; upper beds stromatolitic	4.0
2	Limestone, dark-gray to brownish-black, fine-grained to aphanitic, shaly to medium-bedded; intercalated dark, fissile calcareous shales and platy calcareous mudsone; medium-bedded, irregular, stromatolitic layers and closely associated edgewise conglomerate	15.3
1	Shale, dark-gray to grayish-black, fissile; intercalated fine-grained, laminated dolomite; upper few inches a platy, fine-grained dolomite	3.0
	Total thickness Sconondoa Member	30.0

Note: Base of measured section at about 480 feet

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154. Along Sconondoa Creek beginning a few feet south of Route 5 in Vernon and extending south-southeast to a point 0.2 mile north of Oneida Road; Oneida quadrangle

Vernon Shale		
9	Shale, green, overlain by red shale; exposed in meander bank on east side of Sconondoa Creek; elevation at base of exposure about 690 feet	20.0±
8	Covered; if few inches of green shale exposed in unit 9 is basal unit of Vernon, most of underlying covered interval (see also unit 8 below) represents Lockport	6.0±
Lockport Formation		
Sconondoa Member intertonguing with Ilion Member		
8	Covered (continued from above)	25.0±
7	Shale, grayish-black, silty-textured to smooth, fissile to platy to lumpy; sporadic thin layers of grayish-black to dark-gray, laminated, pyritiferous mudstone; beds at top consist of shales and medium-bedded stromatolitic, calcareous dolomite; this exposure in meander cut bank 0.2 mile east of Stuhlman Road	10.0±
6	Covered	4.0–5.0

5	Shale, dark, calcareous; interbedded dark-gray to grayish-black, medium-bedded, edgewise conglomerate in limestone; stromatolite layer; finely disseminated pyrite (exposure just east of Stuhlman Road bridge)	4.0
4	Covered	4.0
3	Limestone, grayish-black to dark-gray, aphanitic to fine- to medium-grained, medium-bedded, stromatolitic; associated edgewise conglomerate (these algal? masses well displayed at this locality); interbedded grayish-black and dark olive-gray, fossiliferous shales — *Lingula* and small pelecypod; shales fissile to platy; lower foot or so covered	10.0
2	Limestone, dark-gray to bluish-black; fine-grained to aphanitic, medium- to thick-bedded; stromatolitic layers associated with edgewise conglomerate consisting of fragments of algal reefs embedded in matrix of slightly coarser, though still fine-grained limestone; a poorly preserved specimen of *Favosite*; minor thin sequences of shale; about 4 feet above base of unit is medium-gray, medium-bedded layer of very fossiliferous limestone, including brachiopods, *Hormotoma*, and *Favosite*; at base of unit, and capping waterfall 0.2 mile south of Route 5 is bed of slightly calcareous dolomite	11.0±
1	Shale, grayish-black, platy to fissile to paper-thin, smooth and soft to silty-textured and harder; fossiliferous including brachiopod-pelecypod assemblage of small forms, some pyritized; interbedded medium-bedded, medium-gray to dark medium-gray, fine- to medium-grained, slightly calcareous dolomite containing *Hormotoma*; sporadic vugs containing calcite; one layer ripple-marked (oscillation and interference); stromatolite tongues present but rare in this interval; at base is 4-inch dolomite layer with sporadic crinoid fragments	8.0
	Total thickness of Lockport Formation	75.0±

Note: Next ledge downstream represents uppermost Herkimer; the surface is irregular; crinoidal; weathers red and green; very mineralized — pyrite and hematite; below are sporadic outcrops nearly to Route 5

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156. Section along creek south of Lairdsville; Rome quadrangle

Vernon Shale	
6 Shale and mudstone, moderate yellowish-green to light-green, lumpy; basal beds mudcracked; overlain by red Vernon which was not traced farther upstream.	5.0
Lockport formation	
Ilion Member	
5 Shale, dark-gray to grayish-black, fissile to paper-thin, soft; interlaminated with dark greenish-gray to light greenish-gray shale of same texture; 2–3 inch thick mudstone beds, dark-gray to dark greenish-gray; lingulids upper part transitional to basal Vernon	6.5
4 Dolomite, grayish-black, fine- to medium-grained, medium- to shaly-bedded, sandy-textured; laminated; sphalerite; pyrite especially abundant near top; stromatolitic layers and intraformational conglomerates; *Howellella* and *Pterinea* present near base; intercalated dark, thin- to shaly-bedded, platy dolomitic mudstone and argillaceous dolomite; layers containing profusion of *Lingula*	6.8
3 Shales and mudstones, grayish-black to medium dark-gray, fine-grained, platy to lumpy; few thin layers of impure dolomite; sporadic lingulids	2.3–3.3
2 Dolomite, grayish-black, medium-grained, sparkling, thin- to medium-bedded; intercalated shaly-bedded dolomite; stromatolitic	6.8–7.8
1 Shale, greenish-black, fine-grained, lumpy, slightly dolomitic; interbedded dark, finer-grained, smooth, fissile shale; beds of dark greenish-gray claystone and shales; sporadic lingulids	6.7
Total thickness of Ilion Member	30.1

Note: Below is covered interval representing about 30 feet, stratigraphically. In this interval, blocks of aphanitic algal limestone and edgewise conglomerate were found, although none were seen in place. The Herkimer Formation exposed sporadically along creek below elevation of about 750 feet; upper part a medium-gray, medium-bedded, crinoidal calcareous dolomite.

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158. East-flowing creek on College Hill about 0.5 mile north of the words "HAMILTON COLLEGE" on the Clinton 7½ minute quadrangle; Rome quadrangle

Vernon Shale		
30	Shale and mudstone, green, overlain by typical red Vernon	—
29	Covered; about 4 feet represents Vernon	4.0
Lockport Formation		
Ilion Member		
29	Covered; continued from above	12.0
28	Dolomite, medium-gray, fine-grained, resistant; ropy surface	0.3
27	Shale, chippy; interbedded thin, fine-grained to aphanitic claystones and argillaceous dolomites	1.5
26	Dolomite, medium dark-gray, fine-to medium-grained, stromatolitic, upper pillow-shaped surface covered with small nodules; shales fill in irregularities between domes	1.0–1.3
25	Dolomite, compact, argillaceous; shaly partings	0.5–0.6
24	Shale, dark, fissile, becomes harder and more dolomitic toward top	2.3
23	Dolomite, dark-gray, fine-grained, argillaceous, weathers light brown	0.2
22	Mudstone, medium dark-gray to dark-gray, fine-grained to very fine-grained, hard, dolomitic; interlaminated fine- to medium-grained argillaceous dolomite; upper 3 feet predominantly lumpy to fissile, light-gray weathering shale	8.5
21	Shale, grayish-black, soft, fissile	7.3

20	Shale, dark, platy to fissile, alternating with 2–4 inch beds of intraformational conglomerate; soft, olive-gray shale at top	4.0
19	Dolomite, medium dark-gray, fine- to medium-grained; stromatolitic, convex upper surface elongate N80°W; associated edgewise conglomerate; ropy surface (this unit located under footbridge)	2.0±
18	Dolomite, medium-gray, fine-grained, thin-bedded; intercalated platy, dolomitic shales	0.5
17	Covered	3.5
16	Dolomite, medium-gray, medium-bedded, fine- to medium-grained, calcareous; (Herkimer-like lithology); lower part a coarser intraformational conglomerate consisting of elongate, commonly curved intraclasts; upper part more porous; contains braciopod fragments; calcite, sphalerite	0.5
15	Shale, gray; fissile toward top	1.5
14	Shale and mudstone, platy and hard to softer, fissile; dolomitic; laminations of argillaceous dolomite; one bed having ropy surface, orientated N80°W	4.0
13	Dolomite, dark-gray, fine- to medium-crystalline, pillow-shaped (stromatolitic); also dark-gray, platy, hard dolomitic shale; uppermost part has intraformational conglomerate; upper surface ropy; calcite, sphalerite	3.0
12	Dolomite, grayish-black, fine- to medium-grained, medium-bedded, shaly partings	1.5
11	Shale, dark-gray, platy to fissile, dolomitic; olive-gray shales at base	2.7
10	Dolomite, dark-gray to grayish-black, medium-grained, glistening; resistant; stromatolitic	1.0
9	Shale, gray, lumpy to fissile	2.5
8	Dolomite, medium-gray, fine- to medium-grained	0.2
7	Shale, grayish-black, platy to fissile to paper-thin; small lingulids and fragments of other fossils; grades into overlying	3.0
6	Covered	1.0
5	Dolomite, medium-gray to medium dark-gray,	

medium-bedded; elongate mudstone pebbles; disseminated pyrite, sphalerite.............. 0.5

4 Shale, dark greenish-gray to olive; fossiliferous layer in middle-*Howellella* and *Pterinea*...... 1.2

3 Dolomite, medium light-gray to medium dark-gray, medium-grained; resembles lithology of underlying Herkimer but not crinoidal; *Favosites* and brachiopod fragments.............. 0.2

2 Shale, dark greenish-gray to olive-gray to yellowish olive-gray, soft, platy to fissile, fossiliferous 2.0

Total thickness of Ilion Member................ 70.0±

Herkimer Sandstone

1 Dolomite, medium light-gray to medium-gray, medium- to thick-bedded, slightly calcareous and siliceous, crinoidal; coarse crinoid fragments in medium-grained matrix; disseminated pyrite; pods of darker mudstone at top; surface undulating, but undulations aligned and probably due to ripple marks; digging exposed "contact" with overlying Ilion-thin clay zone followed by grayish-black to greenish-black shales..... 5.1

Note: The Ilion-Herkimer contact, as drawn between units 1 and 2, at elevation of about 740 feet; Herkimer well exposed below

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166. South branch of Moyer Creek; Utica quadrangle

Vernon Shale

20 Shale, greenish-gray to dark greenish-gray, smooth, fissile; becomes lumpy above lower foot; red Vernon overlies basal green Vernon and is exposed in banks immediately upstream.. —

Lockport Formation

Ilion Member

19 Shale, olive to black, fissile to paper-thin; weathers gray; upper foot contains greenish-gray laminations; upper contact transitional.. 2.0

18 Dolomite, dark greenish-gray to dark-gray, medium-grained, stromatolitic, compact; lami-

	nated; pyritiferous; interbedded greenish-gray shales	1.5
17	Shale, olive-black, fissile to platy; intercalated greenish-gray shale toward top; intertonguing stromatolitic layers with associated shale; also olive-gray, paper-thin shales	2.0
16	Shale, greenish-gray to dark greenish-gray shale; interlaminated with typical olive-black shales of Ilion	0.2
15	Shale, dark-gray to olive-black; zone of clay in this interval; thin bed of mudstone containing numerous small lingulids; layer of intraformational conglomerate	0.4
14	Shale, greenish-gray to dark greenish-gray, platy; "concretions" of olive-black mudstone	0.3
13	Shale, olive-black, smooth, fissile; sporadic thin layers of medium-gray mudstone	1.5
12	Shale, medium dark-gray to dark-gray, fissile to platy, thinly laminated; sporadic intercalated laminations of olive-gray shale; medium-gray, fine-grained, thin-bedded dolomite containing disseminated pyrite	2.2
11	Mudstone, medium dark-gray, fine-grained, thin- to shaly-bedded, dolomitic; intercalated lenses of medium-gray, medium-grained, stromatolitic dolomite; vugs in latter, enclosing large dolomite rhombs, sphalerite, and pyrite; fissile shales	3.5
10	Mudstone, medium-gray to medium dark-gray, thin- to medium-bedded, compact, dolomitic; intercalated shales.	1.5–2.0
9	Covered	1.5
8	Mudstone, dusky-yellow to pale-olive, dense, thin-bedded, contorted; thin laminations of fine-grained, medium-gray dolomite	0.5
7	Shale, olive-gray to dark-gray to greenish-gray, soft, fissile to platy	1.5
6	Dolomite, medium dark-gray, medium-grained, thin-splitting, uneven, argillaceous; iron stained; interbedded dark greenish-gray mudstones and smooth, greenish-black shales; *Favosites* and unidentified brachiopod	2.0

5	Shale, greenish-gray to olive-gray to dark-gray, smooth, fissile to paper-thin; interbedded medium dark-gray, fine-grained, shaly-bedded dolomite; some of latter contain shale pebbles; light olive-gray, shaly-bedded, slightly dolomitic mudstone toward top; unfossiliferous........	2.5
4	Sandstone, greenish-gray to dark greenish-gray, medium-bedded, dolomitic; laminated; stromatolitic; intercalated platy dolomitic mudstone, olive-gray and dark-gray, fissile to paper-thin shale; stromatolites grade laterally to thinner-bedded mudstone and shale.............	3.5
3	Shale, grayish-black, fissile to platy, grading upward to grayish-black shale interlaminated with fissile to paper-thin, olive-gray to moderate yellowish-green shales having bedding surfaces stained by iron oxide; lower part fossiliferous in thin zones — *Pterinea, Howellella,* and *Lingula*; upper part has thin beds of fine-grained dolomitic mudstone and sporadic layers of fine-grained dolomite; thin quartzose dolomites above Herkimer contact at 1,060 feet...	7.0
	Total thickness of Ilion Shale Member.........	33.0±
	Herkimer Sandstone	
2	Dolomite, medium-gray to olive-gray, medium- to coarse-grained, medium-bedded, siliceous; sporadic crinoid fragments; limonitic; layer of intraformational conglomerate toward top; 1-inch layer of gray shale similar to Ilion below upper bed of Herkimer; fossiliferous, including tentaculitids, *Hormotoma*	1.7
1	Sandstone, greenish-gray, medium-to coarse-grained, thin- to medium-bedded; mottled with limonite; section arbitrarily begun in upper layers of small falls just below contact with Ilion..	—

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169. Sporadic outcrops in and along Steele Creek just north of junction of Beckus Gulf road and Route 51; Winfield quadrangle

Vernon Shale

21	Shale and mudstone, red	—
20	Shale, dusky yellow-green to dark greenish-gray, smooth, platy; alternates with greenish-gray to medium dark-gray, thin-bedded mudstones and siltstones; upper foot a dusky yellow-green to grayish olive-green that grades through an inch of reddish mottled shales to the overlying red Vernon; profusion of lingulids which characterize Ilion in sections to west	2.3
19	Dolomite, reddish-gray to greenish-gray, dense, hematitic, pyritic	0.3–0.5
18	Shale and mudstone, greenish-gray, fine-grained, silty-textured; contains small, dark-green to black nodules	0.6–1.4
17	Claystone, greenish-gray, dense, thin-bedded, dolomitic; dark shaly seams randomly oriented; reddish mottles; (this unit as well as 18 and 19 may be considered transitional between Ilion and Vernon	0.8–1.5

Lockport Formation

Ilion Shale Member

16	Dolomite, dark-gray to medium dark-gray, medium-grained, stromatolitic; greenish-gray and reddish mottles; pyrite	1.0
15	Covered	2.0±
14	Dolomite, dark-gray to brownish-gray, medium-grained, medium-bedded, stromatolitic; quartz, pyrite	0.5
13	Shale, greenish-olive, soft, fissile to platy; thin zone containing *Howellella* and pelecypod (*Pterinea*?); immediately above this zone is 1-inch bed of light-gray quartzite	1.7
12	Clay, silty, brownish-orange; capped by blackish, slightly irridescent, unconsolidated material	0.1
11	Dolomite, gray, argillaceous; fossiliferous; upper layer orange-brown; fossils include *Howellella* and fragments of other brachiopods, such as *Homeospira*(?); bryozoans	0.3

10	Dolomite, greenish- to brownish-olive, calcareous; fossils include *Favosites*, *Howellella*, and other brachiopods; sphalerite, galena	0.4
9	Shale, light olive-brown, and dolomite, dark-gray, thin- to medium-bedded; latter contains shale pebbles, pyrite; *Favosites*, *Howellella*	1.5
8	Quartzite, gray; elongate mudstone pebbles; capped by numerous leperditiids; immediately overlying are brownish paper-thin shales	0.5
7	Covered	3.0±
6	Shale, grayish-black and intercalated olive, soft, fissile to platy shale; yellowish-brown (weathered?) zones; at top is medium-gray to medium dark-gray, medium-bedded, fine-grained, siliceous dolomite	4.3
5	Covered	1.0—
4	Shale, gray to olive, fissile to paper-thin; weathered, orange-brown layers or laminations; intercalated dolomitic mudstone; *Favosites*; flat-pebble conglomerate beds; fragments of brachiopods of Herkimer? affinity; at base is 3-inch greenish-gray sandstone mottled with specks of limonite	4.5
	Total thickness of Ilion Shale Member	20.8±
	Herkimer Sandstone	
3	Dolomite, orange-brown, thin- to medium-bedded, crinoidal, siliceous; intercalated smooth, fissile, olive-gray to greenish-olive shales	1.5±
2	Shale, olive-gray to greenish-olive, and interbedded brownish, crinoidal, siliceous dolomite	3.0±
1	Sandstones and sandy shales of Herkimer exposed for about 100 yards to north	—

Appendix III

COMMENTS ON SYSTEMATIC PALEONTOLOGY

INTRODUCTION

Conservatism has been the keynote in the preparation of the faunal lists. This approach is necessitated by a number of factors. Fossil preservation, particularly in the dolomites, is poor. The systematics of several of the taxonomic groups is unsettled. Furthermore, time has not permitted as thorough a comparison with type specimens and other Silurian collections as would be necessary for more specific identifications. For these reasons, it is felt that the identifications appearing in the fossil lists are carried as far as is justified at this time.

Identifications were made in the field and laboratory. Thin sections and polished sections were used in the identification of many of the stromatoporoids, corals, and bryozoans. Forms that are important stratigraphically have been sent to appropriate paleontologists for identification or to check identifications made by the writer. All fossils in the lists have been collected during the present investigation. Following are some pertinent remarks concerning various groups.

STROMATOLITES

The writer agrees with Cloud (1942) that stromatolites should not be assigned formal generic and specific names. The term " stromatolite " seems appropriate and unambiguous with respect to the Lockport, because the structures are unknown in underlying and overlying units. Neither does there appear to be any consistent zonation of particular forms within the formation.

STROMATOPOROIDS

A detailed study of the stromatoporoids is being undertaken as part of a larger project by Dr. Joseph St. Jean, Jr., of the University of North Carolina. Thin sections reveal that previously unreported genera and probably some new species are present in the Lockport. So far as is known, the genus *Clathrodictyon* is the sole member of the Clathrodictyidae reported from the Lockport of New York. The writer found sporadic colonies consisting of continuous laminae and expanding pillars. These structures are more characteristic of the genus *Anostylostroma* than *Clathrodictyon,* which has a skeleton composed of cyst plates.

CORALS

Hall's *Syringopora? multicaule* has been recently placed in the genus *Palaeophyllum* by Oliver (1963).

Favosites and *Cladopora* are the most abundant corals in the Lockport of western New York. Paleontologists have defined the various species of *Favosites* on the basis of the size of the corallites, spacing of the tabulae, and the presence and arrangement of mural pores. Nearly every specimen of *Favosites* examined showed variations in these structures. Some variations may not be inherent but due rather to poor preservation. Few corallites were noted with diameters greater than 2 mm. *Favosites niagarensis,* the most abundant species, includes those club-shaped to somewhat hemispherical coralla having corallites averaging about 1.5 mm. in diameter. One specimen of *Favosites pyriforme,* as described and illustrated by Hall (1852, p. 123, Pl. 34A), was found in the Gasport at Pekin (Tonawanda quadrangle). Other specimens of *Favosites* were assigned the letters A, B, or C, depending primarily on the size and shape of the corallum. Admittedly, this probably is not the best approach to a division of the genus; consequently, the letter designations are not intended to connote that the forms necessarily represent distinct species. However, because the other characteristics show considerable variation within most colonies, it seems advisable to set up the following scheme:

Favosites sp. A	Corallum hemispherical, over 4.0 cm. in diameter; mural pores seldom present; tabulae rather evenly spaced; corallites from 0.5 to 2.0 mm. in diameter.

Favosites sp. B	Corallum hemispherical to spherical or globular, less than 4.0 cm. in diameter; most corallites between 1.0 and 2.0 mm. in diameter; spacing of tabulae variable.
Favosites sp. C	Corallum flat, discoid; corallites 1.5 to 2.0 in diameter.

From Stumm's work (1960), it appears that *Coenites* and *Cladopora* should be considered separate genera. They are separated on the basis of the presence of septal ridges, tabulae, and a marginal thickening of corallite walls in *Coenites,* and a lack of these features in *Cladopora.* Hall (1852, pp. 137–141) described several species of *Cladopora* from the Lockport. Most of these were collected by this writer; although some corallite apertures are lunate, none show septal spines or ridges. Tabulae were not seen in those sectioned. Thus, the specimens are referred to *Cladopora* and the various species are based on Hall's original descriptions.

All favorably preserved halysitid corals collected possess mesocorallites and accordingly should be placed in the genus *Halysites* (Buehler, 1955). In most instances, identifications could not be made lower than the generic level, owing to the poor preservation and the consequent difficulty in distinguishing the shape of the lacunae.

BRACHIOPODS

The genus *Howellella* is important in establishing stratigraphic relations within the Lockport of New York. The status of many species assigned to *Howellella* is problematical at present (A. J. Boucot, 1961, personal communication). Something of the problem can be seen from the obvious differences between the *Spirifer crispus* of Hall (1852, Pl. 54) and Clarke and Ruedemann (1903, Pl. 4).

As was pointed out by Boucot (1957, p. 315), in addition to possessing a lamellose ornamentation and a fold and sulcus, *Howellella* has a coarse ornamentation consisting of relatively smooth flanks, a few plications, or a larger number of plications. An informal distinction, based solely on the external features, can be made among the forms of *Howellella* in the Lockport as follows (with more study, these forms may be found to represent different species):

Howellella sp. A	At least three plications on either side of fold and sulcus; similar to Hall's *Spirifer crispus.*

Howellella sp. B	One or two distinct plications on each side of fold and sulcus.
Howellella sp. C	Smooth flanks or a faint plication bordering fold and sulcus; resembles *Spirifer bicostatus* of Hall (1852, Pl. 54) and *Spirifer crispus* and *Spirifer* cf. *bicostatus* of Clarke and Ruedemann (1903, Pl. 4, excluding fig. 10).

Ruedemann (1916, pp. 67–69, Pl. 24) first described *Lingula semina* from the Pittsford and *Lingula vicina* from the " Bertie waterlime " (actually Ilion Member) at Farmers Mills in the Rome quadrangle. His type specimens have been examined by the writer. With few exceptions, the linguloids collected resemble *Lingula semina* rather than *Lingula vicina*. The greatest width of the valves is generally midway between the anterior and posterior ends, whereas in *Lingula vicina* the anterior end is distinctly wider. Also, most of the valves project slightly at the beak, a characteristic of *Lingula semina*. Several, however, are not as flat as the type *Lingula semina,* and these may represent a gradation between the two species.

PELECYPODS

The most abundant and persistent pelecypod in the Oak Orchard, Sconondoa, and Ilion Members is assigned to the genus *Pterinea*. Some forms resemble the genus *Leiopteria*. Dr. N. D. Newell (1961, personal communication) favors *Pterinea,* but mentioned that there may be no essential difference between the genera. Dr. Thomas Bolton (1962, personal communication), of the Canadian Survey, examined some of the specimens; he agreed that most are placed, with certainty, in the genus *Pterinea*.

OSTRACODES

Dr. Jean M. Berdan, of the United States Geological Survey, has identified several representative ostracodes from the Lockport. Except for leperditiids, ostracodes have not been reported previously from the Lockport of New York. The genera identified include *Herrmannina, Eukloedenella, Kloedenia, Dizygopleura,* and *Mirochilina*. Dr. Berdan plans to make a more detailed study of these forms.

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by

Thomas J. M. Schopf
Temporary Geologist
New York State Museum and Science Service

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Contents

PAGE
1 ABSTRACT
3 INTRODUCTION
5 ACKNOWLEDGMENTS
7 METHODS OF STUDY
11 STRATIGRAPHY
  11 Nomenclature
  13 Biostratigraphy
    13 Conodont-group nomenclature
    22 Early Wilderness fauna
    23 Late Wilderness fauna
    23 Barneveld fauna
  24 Local correlation
  27 Regional correlation
    27 North America
    29 Europe
31 SYSTEMATIC PALEONTOLOGY
  31 Systematic descriptions
    31 Genus *Acodus*
      31 *A. inornatus* Ethington
      32 *A. numaltipes* Schopf, n. sp.
      32 *A. similaris* Rhodes
      33 *A.* aff. *A. unicostatus* Branson & Branson
    34 Genus *Acontiodus*
      35 *A. falcatus* Ethington?
      35 *A.? curvus* Schopf, n. sp.
    38 Genus *Ambalodus*
      38 *A. elegans* (Rhodes)
      38 *A. pulcher* (Rhodes)

SMITHSONIAN INSTITUTION JUL 7 1966

PAGE
39 *A. triangularis* Branson & Mehl
40 Genus *Amorphognathus*
40 *A. ordovicica* Branson & Mehl
41 *A. tvaerensis* Bergström
41 Genus *Belodina*
41 *B. compressa* (Branson & Mehl)
42 *B. diminutiva* (Branson & Mehl)
43 *B. dispansa* (Glenister)
43 *B. inclinata* (Branson & Mehl)
44 *B. ornata* (Branson & Mehl)
44 Genus *Bryantodina*
44 *B. abrupta* (Branson & Mehl)
45 Genus *Coelocerodontus*
45 *C. tetragonius* Ethington
45 *C. trigonius* Ethington
45 Genus *Cordylodus*
45 *C. delicatus* Branson & Mehl
47 *C. flexuosus* (Branson & Mehl)
48 *C.* n. sp.
49 Genus *Dichognathus*
49 *D. brevis* Branson & Mehl
49 *D. typica* Branson & Mehl
51 Genus *Distacodus*
51 *D. falcatus* Stauffer
51 *D. procerus* Ethington
52 *D.? trigonius* Schopf, n. sp.
53 Genus *Drepanodus*
54 *D. amoenus* Lindström
54 *D. planus* Lindström
54 *D. suberectus* (Brandon & Mehl)
55 *D.* sp. cf. *D. arcuatus* of Lindström (1955)
55 *D.* sp. cf. *D. homocurvatus* Lindström
55 Genus *Eobelodina*
55 *E. fornicala* (Stauffer)

PAGE

56 Genus *Falodus*
56 *F. prodentatus* (Graves & Ellison)
57 Genus *Goniodontus*
57 G. *superbus* Ethington
57 Genus *Holodontus*
58 *H. superbus* Rhodes
58 Genus *Icriodella*
58 *I. superba* Rhodes
59 Genus *Ligonodina*
59 *L. tortilis* Sweet & Bergström
59 Genus *Oistodus*
59 *O. abundans* Branson & Mehl
60 *O. inclinatus* Branson & Mehl
61 *O. pseudoabundans* Schopf, n. sp.
62 *O. venustus* Stauffer
63 Genus *Ozarkodina*
63 *O.* sp. cf. *O. tenuis* Branson & Mehl
64 Genus *Paltodus*
64 *P. dissimilaris* (Branson & Mehl)
64 Genus *Panderodus*
65 *P. arcuatus* (Stauffer)
65 *P. compressus* (Branson & Mehl)
66 *P. feulneri* (Glenister)
66 *P. striatus* (Stauffer)
67 Genus *Periodon*
67 *P. aculeatus* Hadding
68 Genus *Phragmodus*
68 *P. undatus* Branson & Mehl
68 *P. cognitus* Stauffer?
69 Genus *Polyplacognathus*
69 *P. bilobata* Schopf, n. sp.
70 *P. ramosa* Stauffer
70 Genus *Prioniodina*
70 *P. macrodentata* (Graves & Ellison)

PAGE
71 *P. pulcherrima* Lindström
72 *P. robusta* (Stauffer)
72 Genus *Rhipidognathus*
72 *R. paucidentata* Branson, Mehl, & Branson
73 Genus *Rhynchognathodus*
73 *R. divaricatus* (Rhodes)
74 *R. typicus* (Ethington)
74 Genus *Rosagnathus*
76 *R. delicata* (Branson & Mehl)
77 Genus *Sagittodontus*
77 *S. dentatus* Ethington
78 *S. robustus* Rhodes
78 Genus *Scolopodus*
78 *S. insculptus* (Branson & Mehl)
79 Genus *Trichonodella*
79 *T. barbara* (Stauffer)
79 *T. exacta* Ethington
80 *T. flexa* Rhodes
81 *T. recurva* (Branson & Mehl)
82 *T.? tricurva* Schopf, n. sp.
83 Genus *Zygognathus*
83 *Z. deformis* (Stauffer)
83 "Fibrous" conodonts
84 Conodont-like fossils
85 **LITERATURE CITED**

Illustrations

PAGE

FIGURE 1.
Classification of Middle Ordovician rocks in New York and southern Ontario 4

FIGURE 2.
Index map showing location of sections collected 6

FIGURE 3.
Stratigraphic extent of rocks exposed at sections collected 8

FIGURE 4.
Distribution of some conodont peak zones in Trenton Group strata, New York, Ontario, and Quebec 20

FIGURE 5.
Correlation of the Trenton Group 26

FIGURE 6.
Outline drawings of some conodonts 36

FIGURE 7.
Outline drawings of some conodonts 50

TABLE 1.
Literature references to sections collected 10

TABLE 2.
Summary of named conodont-groups 14

TABLE 3.
Conodont species abundance and distribution In pocket

TABLE 4.
Conodont distribution, part 1: Wilderness and early Barneveld: Ingham Mills; City Brook; Martinsburg, Roaring Brook In pocket

PAGE

TABLE 5.
Conodont distribution, part 2: Wilderness and early Barneveld: King Falls, Deer River; Dexter Quarry; Rockland Quarry In pocket

TABLE 6.
Conodont distribution, part 3: Wilderness and early Barneveld: Hull Cement Quarry; Kirkfield Quarry; Coboconck Quarry; Lowville In pocket

TABLE 7.
Conodont distribution, part 4: Barneveld: Trenton Falls In pocket

TABLE 8.
Conodont distribution, part 5: Barneveld: City Brook; Martinsburg, Roaring Brook; Martinsburg, Atwater Creek In pocket

TABLE 9.
Conodont distribution, part 6: Barneveld: Deep River; Gulf Stream In pocket

PLATE 1.
Conodonts 95

PLATE 2.
Conodonts 97

PLATE 3.
Conodonts 99

PLATE 4.
Conodonts and Brachiopod 101

PLATE 5.
Conodonts 103

PLATE 6.
Conodonts 105

Conodonts of the Trenton Group (Ordovician) In New York, Southern Ontario, and Quebec[1]

by Thomas J. M. Schopf[2]

ABSTRACT

Type area collections of approximately 55,000 identifiable conodonts from 195 limestone samples collected from 12 sections of the Trenton and middle and upper part of the Simcoe Groups, and 370 conodonts from 19 samples mainly from two sections of the underlying Black River and lower part of the Simcoe Groups are the basis for zonation and correlation suggested here. In Trenton and middle and upper Simcoe Group collections, 69 species, seven of which are newly named or described, are referred to 32 genera. "Fibrous" conodonts are not described. New species are *Acodus numaltipes, Acontiodus? curvus, Distacodus? trigonius, Oistodus pseudoabundans, Polyplacognathus bilobata, Trichonodella? tricurva,* and an unnamed species of *Cordylodus.* Several "conodont-groups" are suggested; these are based on common occurrence of conodont species.

Black River and lower Simcoe Group conodonts are characterized by "fibrous" forms, whereas Trenton genera are almost exclusively non-fibrous. Except in basal Trenton beds, which contain a few European species, conodont faunas of the Rockland, Kirkfield, and lower part of the Shoreham Formations, of Wilderness and lower

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[1] Manuscript submitted for publication May 1, 1965.

[2] Research Associate—Marine Biological Laboratory, Woods Hole, Mass.

Barneveld age, are North American midcontinent in aspect, and are characterized by the *compressa-* and *ramosa*-groups. These groups are replaced in middle to upper Shoreham beds by typically European conodonts including the *aculeatus-, superba-,* and *ordovicica*-groups, and by *Holodontus* and *Rosagnathus.* The succeeding Denmark, and especially Cobourg Formations, have both European and midcontinent conodonts well represented.

The Trenton Group conodont sequence is like that in the Middle and lower Upper Ordovician rocks of the Middletown core, southwestern Ohio (Sweet & Rust, 1962), and in the Upper Mississippi Valley. The Rockland, Kirkfield, and lower Shoreham Formations are correlated with the lower part of the Lexington Group, and with the Decorah Formation. The faunal break in the Shoreham has been reported previously in the middle Lexington and is suggested in the Decorah-Galena transition. The Denmark Formation is correlated with the Cynthiana and Stewartville. The lower Cobourg, Hallowell Member, is correlated with the lower parts of the Eden Formation and Dubuque Member of the Galena Foundation. The upper Cobourg, Hillier Member, is tentatively correlated with remaining Eden and Dubuque strata.

Introduction

The purpose of this paper is to describe the conodonts and and record their sequential occurrence through Trenton Group limestones (figure 1) in their type area of New York, southern Ontario, and Quebec, and to suggest correlations of the Trenton Group based on comparison of conodont sequences. Previously, the conodont faunas of the type Upper Ordovician, Richmondian (Branson, Mehl, & Branson, 1951), Maysvillian (Pulse & Sweet, 1960), and Edenian stages (Sweet *et al.,* 1959) have been described. Correlation of Trenton strata has long been a subject of controversy, and correlation based on the use of a different faunal group from those previously considered provides additional evidence.

The conodonts that form the basis of this study were collected from Trenton and middle and upper Simcoe Group limestones at 12 localities, and from sections that include primarily Black River or lower Simcoe Group limestones at two additional places (figures 2, 3). Two localities, the Kirkfield and Coboconck quarries, are on the continental platform in southern Ontario near Lake Simcoe. Two others, the Rockland and Hull Cement quarries, are in the Ottawa Valley, Ontario, and Quebec. Seven localities are in the Black River Valley, New York, and three in the West Canada Creek Valley, New York, in the eastern part of the continental platform, west of the Adirondack Axis.

<table>
<tr><th colspan="2"></th><th colspan="3">BLACK RIVER VALLEY, NEW YORK</th><th colspan="3">SOUTHERN ONTARIO</th><th colspan="2">OTTAWA — ST. LAWRENCE LOWLAND</th></tr>
<tr><th colspan="2">STAGE</th><th>GROUP</th><th>FORMATION</th><th>MEMBER</th><th>GROUP</th><th colspan="2">FORMATION</th><th>FORMATION</th><th>MEMBER</th></tr>
<tr><td colspan="2" rowspan="4">BARNEVELD</td><td rowspan="6">TRENTON</td><td rowspan="2">COBOURG</td><td>HILLIER</td><td rowspan="8">SIMCOE</td><td colspan="2">LINDSAY</td><td rowspan="9">OTTAWA</td><td rowspan="2">COBOURG</td></tr>
<tr><td>HALLOWELL</td><td colspan="2" rowspan="3">VERULAM</td></tr>
<tr><td>DENMARK</td><td rowspan="7"></td><td rowspan="2">SHERMAN FALL</td></tr>
<tr><td>SHOREHAM</td></tr>
<tr><td rowspan="5">WILDERNESS</td><td rowspan="2">LATE</td><td>KIRKFIELD</td><td>UPPER MEMBER</td><td rowspan="3">BOBCAYGEON</td><td>HULL</td></tr>
<tr><td>ROCKLAND</td><td>MIDDLE MEMBER</td><td>ROCKLAND</td></tr>
<tr><td rowspan="3">EARLY</td><td rowspan="3">BLACK RIVER</td><td>CHAUMONT</td><td>LOWER MEMBER</td><td>LERAY</td></tr>
<tr><td>LOWVILLE</td><td colspan="2">GULL RIVER</td><td>LOWVILLE</td></tr>
<tr><td>PAMELIA</td><td colspan="3">SHADOW LAKE</td><td>PAMELIA</td></tr>
</table>

FIGURE 1. Classification of Middle Ordovician rocks in New York, southern Ontario, and Ottawa—St. Lawrence Lowland.

Acknowledgments

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The writer has greatly benefited from observations and suggestions on conodont systematics by Dr. S. M. Bergström, Lund University, Sweden; Dr. Bergström also very kindly made available topotype and research collections from Welsh and Swedish localities. Mr. G. F. Webers, of the University of Minnesota, freely discussed unpublished information on Stauffer's 1930 types and his own work on the Ordovician conodont sequence in the Upper Mississippi Valley. Dr. C. B. Rexroad, Indiana Geological Survey, kindly gave permission to study Rhodes' (1953) types, which he had borrowed. Mr. L. M. Rychener, of Ohio State University, and Dr. Bergström provided spirited field assistance.

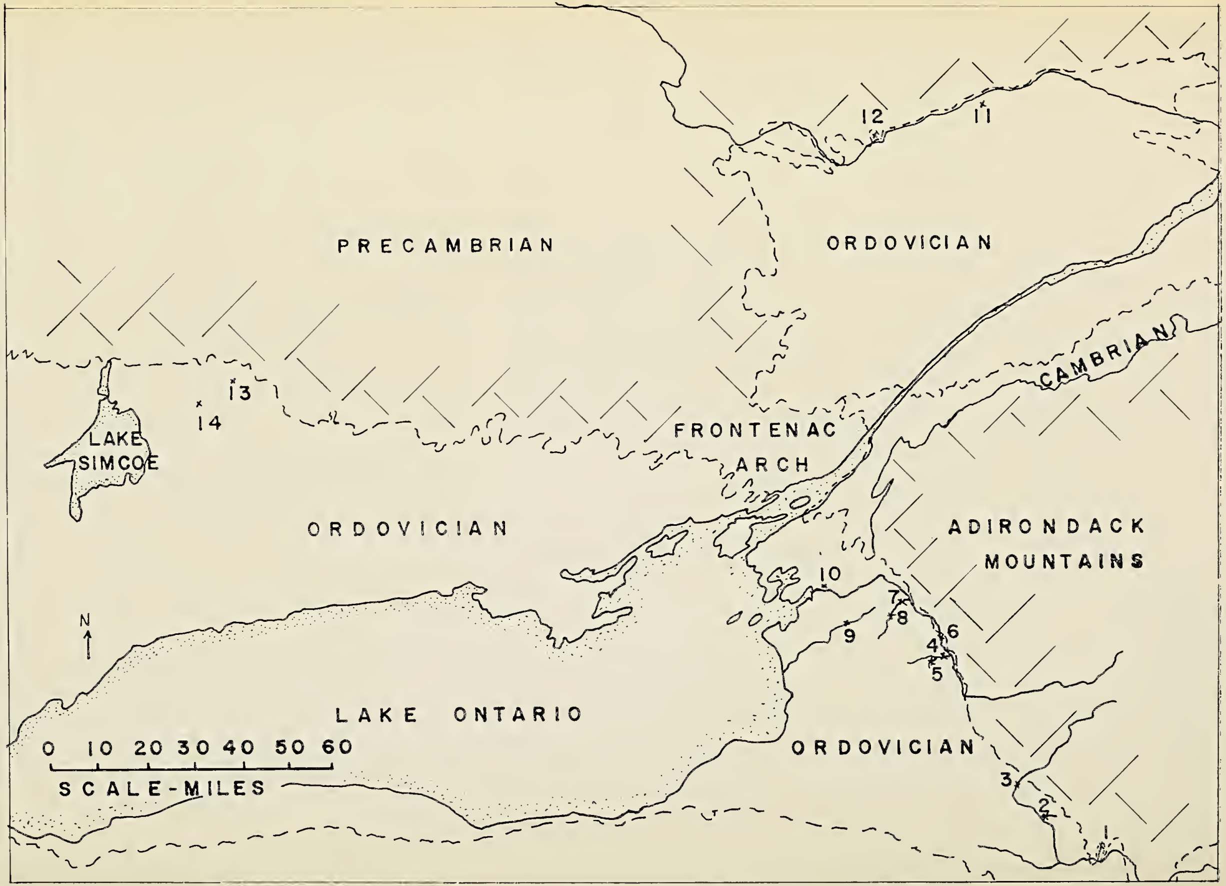


FIGURE 2. Index map showing location of sections collected. Section numbers refer to sections listed in Table 1.

Methods of Study

FOURTEEN PREVIOUSLY DESCRIBED sections of the Trenton, Simcoe, and Black River Groups were sampled at closely spaced intervals. Measured sections used in the study are listed in table 1, and their stratigraphic extent is shown in figure 3. These sections include the type sections of the Trenton Group, and the type sections of the Rockland, Kirkfield, and Denmark Formations. To assure flexibility by having the option of investigating interesting intervals in detail, far more material was collected than was used. In all, more than 1200 samples were taken. From these samples, approximately 175 were selected to provide a general picture of conodont distribution. Additional samples were processed from intervals of particular interest, making the total number processed 214. Five to 10 feet of section separated most adjacent processed samples. Most samples used weighed 500 grams. The average number of identifiable specimens was 250 per sample. The method of processing described by Collinson (1963) was followed. Most Trenton Group insoluble residues are low in dolomite, pyrite, and extraneous phosphatic material; hence conodonts could be effectively concentrated by heavy liquid techniques in mass production. The residue coarser than 100 mesh was searched for conodonts. The minus-100 mesh fraction is preserved in plastic bags for future work on Chitinozoa and other acid-resistant microfossils at the Department of Geology, Ohio State University.

Specimens mounted on an opaque background were photographed through a Leitz Ortholux with Ultropak and accessory incident lighting. Several were mounted on glass slides and photographed with both incident and transmitted light. Prints were enlarged from 35mm film, and plates prepared at more than twice their present size. Specimens from Ontario and Quebec are light amber and similar to conodonts from other North American midcontinent localities in this respect. Most other specimens are dark brown to gray indicating that the organic matter has been partially coalified.

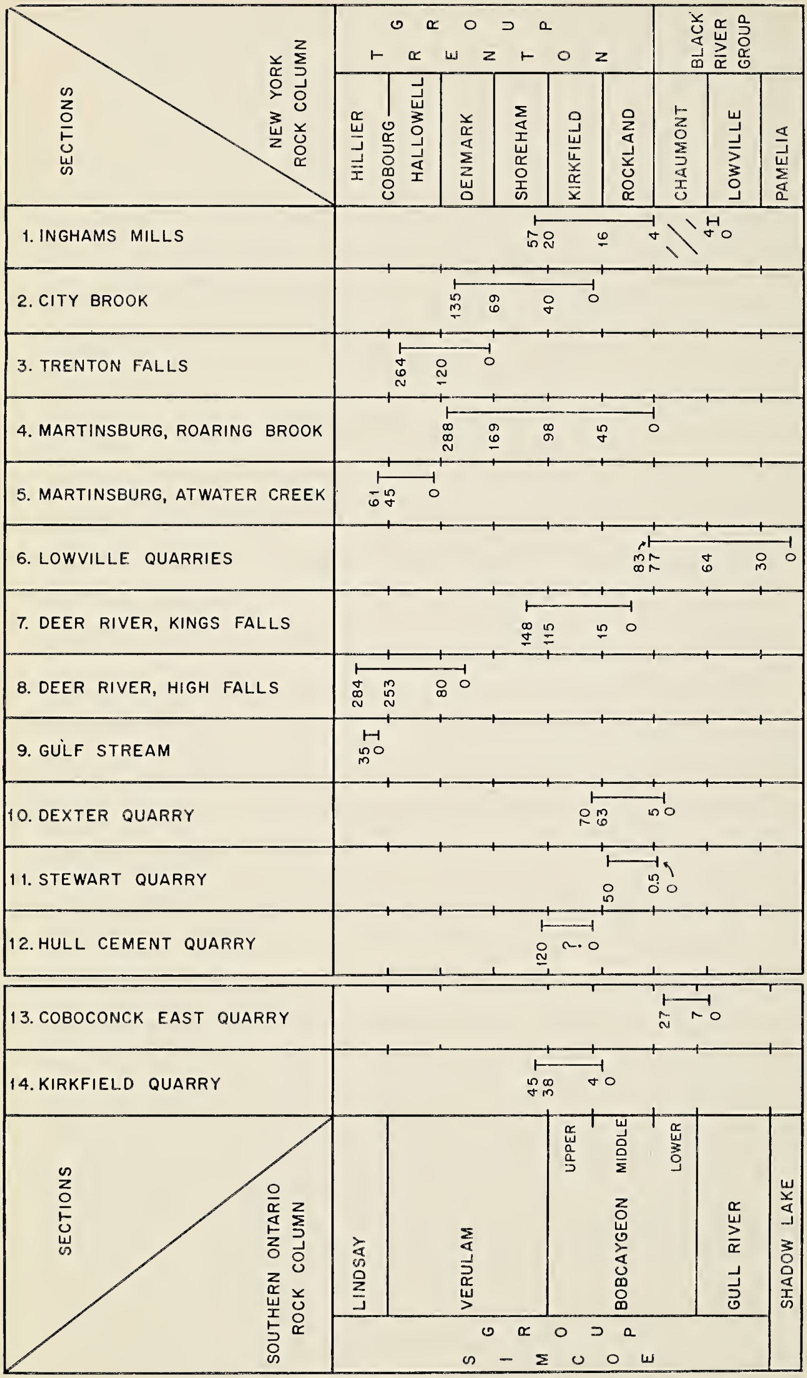


FIGURE 3. Stratigraphic extent of rocks exposed at localities sampled and shown in figure 2. Numbers refer to footage at base and top and to formational contacts within the section collected.

Tables 4-9 give the number of specimens of each species for each sample. In most cases, individual totals were rounded off; those from 25-99 specimens to the nearest 5, those from 100 to 499 to the nearest 10, and those in excess of 500 to the nearest 50. The total number of each species present is given in the faunal list (table 3). The reader may note certain anomalies in the suggested zonation, such as a large number of specimens of the *ramosa* group in the Barneveld (table 8), although this group is said to characterize the Wilderness fauna. Most of such anomalies occur near the Wilderness-Barneveld boundary where samples contained elements of both faunas, and an arbitrary decision was made as to which samples to group in which division. The general pattern of faunal development, however, is not changed.

In a few cases, the number of conodonts in a sample was so large that only one-quarter or one-half of the total collection was picked in its entirety. The remaining portion was picked of all specimens except for *Phragmodus undatus, Dichognathus brevis, D. typica,* and *Oistodus abundans,* and in one case, *Oistodus pseudoabundans.* The total number of these species in the sample was then obtained by multiplying the number picked by the appropriate fraction.

Table 3, Conodont Species Distribution in the Black River, Trenton, and Simcoe Groups, is based on correlation of sections studied, and a judgment of the importance of the same species found in about the same position in two or more sections. Only about 400 Black River Group conodonts were examined in contrast to about 55,000 Trenton Group conodonts. Even considering the extended coverage within the Trenton Group, there is usually from 5 to 11 feet between samples processed, and details of species distribution remain to be worked out.

It was very difficult to distinguish the reclined species of *Drepanodus* and the species of *Panderodus.* Thus, for purposes of tabulation, the designation *Drepanodus* spp. and *Panderodus* spp. were used. The two species of *Dichognathus* were present in nearly every sample although specimens were often fragmentary and difficult to place. Thus, for tabulation, these two species were grouped.

Types are in the collection of the New York State Museum, Albany, New York. A reference collection of identified specimens, bulk collections, and rock collections are at the Department of Geology, Ohio State University.

TABLE 1. SECTIONS COLLECTED

Section Number on Index Map (Figure 1), and Name	Section designation in Micropaleontology Laboratory, OSU	Reference to Measured Section
1. Inghams Mills, New York	62B-IM	Kay, 1937, 1942a.
2. City Brook, Newport, New York	62B-CB	Kay, 1937, 1953.
3. Trenton Falls, Trenton, New York	62B-TR	Kay, 1937, 1953; Ross, 1964.
4. Martinsburg, Roaring Brook, New York	62B-MRB	Chenoweth, 1949, 1950; Ross, 1964.
5. Martinsburg, Atwater Creek, New York	62B-MAC	Kay, 1933.
6. Lowville, New York	62B-LO	Young, 1943 (Section #43).
7. Deer River, Kings Falls, New York	62B-KDR	Kay, 1933, 1937.
8. Deer River, High Falls, New York	62B-DR	Kay, 1933, 1937.
9. Gulf Stream, Rodman, New York	62B-GS	Kay, 1933.
10. Quarry East of Dexter, New York	62B-DQ	Kay, 1937.
11. Stewart Quarry, Rockland, Ontario	62B-RQ	Wilson, 1921; Kay, 1937, 1942b.
12. Hull Cement Quarry, Hull, Quebec	62B-HCQ	Raymond, 1913.
13. Coboconck East Quarry, Coboconck, Ontario	62B-C	Okulitch, 1939; Hewitt, 1960; Liberty, 1964.
14. Kirkfield Quarry, Kirkfield, Ontario	62B-KQ	Hewitt, 1960; Liberty, 1964.

Stratigraphy

Nomenclature

Stable nomenclature of rock units without homonymy of stadial and lithologic names is clearly desirable. In this paper, "Trenton" is used in the sense of Trenton Group; Barneveld is used as a stage designation for part of the Trenton Group (figure 1).

The Trenton Group here includes the limestone sequence above the Chaumont Limestone of the Black River Group and below the dark shales of the Collingwood Formation or its lateral equivalent, the Utica Shale (figure 1). In New York, five formations are recognized in this interval. In ascending order, they are Rockland, Kirkfield, Shoreham, Denmark, and Cobourg. Two members of the Cobourg Formation are recognized; in ascending order, they are the Hallowell and Hillier. In Ontario, rocks of comparable age are units of the middle and upper Simcoe Group (Liberty, 1955, 1964). Specifically, they are the middle and upper members of the Bobcaygeon Formation, and the Verulam and Lindsay Formations.

Exclusion of the Utica Shale from the Trenton Group follows the example of Vanuxem (1838), who was the first to describe these rocks in detail. Conrad, who gave a brief sketch of New York third district geology in 1837, apparently considered the limestones and shales in the same rock unit, and in 1839, he referred to them as "Trenton limestone and slate." Some authors have followed Conrad in including both the limestone and shale units in the same group (Kay 1937, 1960). However, the post-Black River limestone sequence affords an easily defined lithologic sequence. In addition, the term "Utica" has been widely used for the superjacent black shale sequence. Consequently, it seems desirable to recognize form-ally both the limestone and shale facies as separate stratigraphic units, equal in importance, and here considered groups.

Trenton Group rocks are of late Wilderness and Barneveld age. The Rockland and Kirkfield Formations and their correlatives are late Wilderness; the Shoreham, Denmark, and Cobourg Formations are Barneveld.

Black River Group conodonts are characterized by "fibrous" forms; this type is rarely present in the Trenton Group. The prominent Black River Group-Trenton Group conodont faunal division thus argues for local separation of the Wilderness into early and late Wilderness time. DeMott (1964) discussed a break in trilobite faunas also near the Black River Group-Trenton Group boundary in New York and in presumed correlative beds of the Upper Mississippi Valley.

The appropriateness of placing the upper boundary of the Wilderness Stage at the Kirkfield-Shoreham formational boundary has been demonstrated through study of brachiopods (Cooper, 1956) and trilobites (Whittington, 1959) and is suggested by the change in bryozoans at this level (Ross, 1964). The most persistent and recognizable conodont faunal change within the Trenton Group is close to this level (table 3).

A "natural" upper boundary of the Barneveld is not obvious. Kay (1960) has long considered that the top of the Trentonian Stage corresponds with the top of the Utica Shale and with the base of the Eden Formation. From study of cephalopods, Flower (1957) suggests that the lower Cobourg and Eden are correlative. Sinclair (1958, 1964) finds that upper Cobourg, Hillier Member, faunas have a distinctly younger aspect than earlier faunas and he correlates the Hillier with the Eden. Comparison of the Trenton Group conodont sequence with that of the Middle and Upper Ordovician in Kentucky and Ohio (Sweet & Rust, 1962; Sweet *et al.*, 1959) suggests correlation of at least the lower part of the Eden with the lower part of the lower Cobourg, Hallowell Member.

It has been suggested that the Middle-Upper Ordovician boundary be readjusted to the base of the Cobourg (Flower, 1957). However, conodonts of the Denmark and Cobourg Formations are essentially the same and no easily definable faunal break occurs. Rather, the evidence suggests that the conodont fauna which is first known widely in the mid-Shoreham may persist for a considerable time. The medial Upper Ordovician Maysvillian Stage contains conodonts

(Pulse & Sweet, 1960) of the same type that are found in the Eden (Sweet *et al.*, 1959). Conodonts reported from the late Upper Ordovician Richmond Group (Branson, Mehl, & Branson, 1951) contain no genera and only a few species not found in the Barneveld. The Middle-Upper Ordovician interval of time is appreciably shortened if the Eden-Hallowell correlation continues to be substantiated.

Biostratigraphy

Conodont-group nomenclature. — In the course of picking conodonts from the largest of the samples used in this study, it became apparent that many conodont species co-occur in ratios of small whole numbers. If these co-occurrences are indeed natural and predictable, then one can infer, from analysis of samples containing some of these elements, that all of the elements would be present in a larger sample. By being able to make this inference, one may (1) save time in working through samples by only identifying a small percentage of the total sample, and (2) gain increased knowledge of faunas in relatively barren rocks. The following section attempts to demonstrate that these occurrences are natural and predictable.

Counts of nearly all species were made and totals compared among discrete elements which from intuitive inference based on stratigraphic distribution seemed to occur together. The co-occurrences that seemed best supported are given in table 2.

Finally, comparison of the conodont-groups derived from Trenton Group material was made with those conodont-groups independently arrived at from study of tens of thousands of specimens from long stratigraphic successions through the Middle and Upper Ordovician by Dr. W. C. Sweet (Cincinnati Region), and Mr. G. F. Webers (Upper Mississippi Valley). The results were strikingly similar, although responsibility for the conodont-groups suggested here rests solely with the author.

Ultimately valid conodont-groups may be recognized as species (Webers, Schopf, Sweet, in press), but this entails many detailed questions of nomenclatorial priority, and is not attempted here. The conodont-groups suggested here should be tested in other areas.

The identification of conodont-groups is based on common occurrence of conodont species in a ratio of small whole numbers. It must

TABLE 2

SUMMARY OF NAMED CONODONT-GROUPS

Conodont-group	Included Species	Number of specimens	Suggested ratio of occurrence	Absolute ratio of occurrence
undatus-group	*Oistodus abundans*	6,799	4:6:12	4:6.4:11.2
	Dichognathus brevis & *D. typica*	11,122		
	Phragmodus undatus	19,162		
		37,083		
compressa-group	*Eobelodina fornicala*	168	2:10	2:9.6
	Belodina compressa	814		
		982		
ramosa-group	*Polyplacognathus bilobata*	369	2:4	2:4.8
	P. ramosa	886		
		1,255		
aculeatus-group	*Periodon aculeatus*	319	6:8	6:7.9
	Falodus prodentatus	420		
		739		
ordovicica-group	*Ambalodus triangularis*	262	2:4	2:4.2
	Amorphognathus ordovicica	551		
		813		

TABLE 2 *(Continued)*

SUMMARY OF NAMED CONODONT-GROUPS

Conodont-group	Included Species	Number of specimens	Suggested ratio of occurrence	Absolute ratio of occurrence
superba-group	*Sagittodontus dentatus*	23	2:2:4:4:8	1.4:2:3:3.9:7.9
	Rhynchognathodus typicus	32		
	S. robustus	48		
	R. divaricatus	62		
	Icriodella superba	127		
		292		
robusta-group	*Prioniodina robusta*	61	2:4:2:2:2:6	2.4:4:1.4:2:2.6:6
	Ozarkodina cf. *O. tenuis* (Wilderness type)	101		
	Trichonodella barbara	35		
	T. recurva	50		
	Zygognathus deformis	65		
	Cordylodus delicatus & *C. flexuosus*	(131+19) 150		
		462		
pulcherrima-group	*Prioniodina pulcherrima*	187	2:6:2:2:2:10	2.6:6:1.4:1.7:2:9.2
	Ozarkodina cf. *O. tenuis* (Barneveld type)	437		
	Trichonodella exacta	104		
	T. flexa	120		
	Zygognathus deformis	145		
	Cordylodus delicatus & *C. flexuosus*	(383+291) 674		
		1,667		

be based on samples from a long stratigraphic interval. Nearly identical stratigraphic distribution does not necessarily indicate membership in a group. For example, *Oistodus inclinatus* has about the same overall distribution as those species referred to the *undatus*-group, but whereas the species assigned to the *undatus*-group seem to occur in a ratio of small whole numbers, *Oistodus inclinatus* does not bear any simple relationship to these species.

In several cases, such as *Polyplacognathus ramosa* and *P. bilobata,* or, *Acodus inornatus* and *Distacodus procerus,* the species considered to occur together also are similar morphologically. This similarity is not conclusive evidence to suggest the same biological origin, but it seems reasonable to believe that various elements from a single biological species would be alike in certain ways, such as basal cavity characteristics. Similar morphology may be especially good evidence for biologic grouping where the only difference is degree of symmetry caused by differences in surface sculpture.

The size of a sample is important, as small yields may lack uncommon elements. In fact, moderate to large yields may in some samples lack one or more members considered to belong to a group whose other members are represented. In any case, the ratio of occurrence of various elements will vary a great deal among isolated samples. This can perhaps best be interpreted as the result of postmortem sorting. As an example which might be interpreted in this way, Sweet and Bergström (1962), in their study of Pratt Ferry conodonts, found 100 dextral and only 27 sinistral specimens of *Falodus prodentatus.* One would expect equal numbers of dextral and sinistral variations of this element.

The *undatus*-group includes *Phragmodus undatus, Dichognathus brevis, D. typica,* and *Oistodus abundans.* In Trenton Group collections, 37,000 specimens are included in this group, or about 60 percent of the total collection. These conodonts occur in dextral and sinistral forms, and in addition, *Phragmodus* is about four times as abundant as each *Dichognathus* species and three times as abundant as the single *Oistodus* species. Thus it is suggested that two pairs of *Oistodus abundans* were associated with three pairs of *Dichognathus* and six pairs of *Phragmodus,* yielding a total of 22 elements in the natural assemblage. This ratio of 4:6:12 is not precisely that suggested by the actual count of 19,162 *Phragmodus undatus,* 11,122 *Dichognathus* spp., and 6,799 *Oistodus abundans,* whose ratio of occurrence is 4:6.4:11.2. However, in so far as one must try to find the smallest ratio of even whole numbers which fits the data, the ratio of 4:6:12 is considered most probable. Twenty-two elements fall within the range of 14 to 22 elements that have been found in associated conodont assemblages (Rhodes, 1962).

The *compressa*-group includes *Belodina compressa* and *Eobelodina fornicala.* These species are invariably associated in large collections and their stratigraphic distribution in Trenton Group strata is nearly identical. Almost 1,000 specimens, which is about 2 percent of the total collection, are referred to this group. *B. compressa* is about five times as common as *E. fornicala.*

The *ramosa-group* is represented by about 1,250 specimens of *Polyplacognathus ramosa* and *P. bibobata.* Undescribed Platteville conodonts in Ohio State collections include both of these species as do the Decorah (Stauffer, 1935a) and Kimmswick Formations (Branson, 1944). Approximately twice as many *P. ramosa* as *P. bilobata* occur in Trenton Group samples.

The *aculeatus*-group includes *Periodon aculeatus* and *Falodus prodentatus,* and is represented in Barneveld collections by about 700 specimens. The ratio of occurrence of *Periodon* to *Falodus* is 3:4. However, because these are paired elements, the smallest total number of elements in the natural assemblage would have been 14. The *ordovicica*-group includes *Amorphognathus ordovicica* and *Ambalodus triangularis,* and is represented by about 800 specimens. *Amb. triangularis* is about twice as common as is *Amo. ordovicica.*

The *superba*-group includes *Icriodella superba, Sagittodontus robustus, S. dentatus, Rhynchognathodus divaricatus* and *R. typicus.* The more abundant member of each species pair is about equally well represented; *Icriodella,* however, is about twice as common as either of these. Hence it is suggested that for each pair of the least common members, *S. dentatus* and *R. typicus,* there were two pairs of *S. robustus* and *R. divaricatus,* and 8 individuals of *Icriodella,* making a total of 20 elements in the assemblage.

The *robusta-* and *pulcherrima*-groups of Wilderness and Barneveld age respectively, are the least satisfactorily defined of the groups here named. However, because these elements are extremely abundant in most midcontinent collections, it seems useful to attempt to recognize the faunal associations. Insofar as the same types of elements are involved in each group, one would expect the ratios of included species to be the same. However, the numerical ratios for each of these groups are not identical—perhaps 2:4:2:2:2:6 for the *robusta*-group, and, 2:6:2:2:2:10 for the *pulcherrima*-group; (these ratios are obtained by combining the number of specimens of the very similar *Cordylodus delicatus* and *C. flexuosus*). Thus, either the suggested group members are wrong, or not enough specimens are present to overcome the variation from sample to sample.

The inclusion of the same species in both groups perhaps suggests that one group evolved into the other with more change in some members than in others. Placed tentatively in the *robusta*-group are *Prioniodina robusta, Ozarkodina* cf. *tenuis* (of the Wilderness type), a symmetric *Trichonodella* with posterior process denticulation *(T. barbara)*, an asymmetric *Trichonodella* with rounded undenticulated posterior process *(T. recurva), Zygognathus deformis, Cordylodus delicatus,* and *C. flexuosus. Bryantodina abrupta, Rhipidognathus paucidentata,* and *C.* n. sp. may also belong here. This group includes about 500 Wilderness conodonts.

The *pulcherrima*-group tentatively includes *Prioniodina pulcherrima, Ozarkodina* cf. *tenuis* (of the Barneveld type), a symmetric *Trichonodella* with denticulated posterior process *(T. exacta)* and an asymmetric *Trichonodella* with a sharply flexed undenticulated posterior process *(T. flexa), Zygognathus deformis, Cordylodus delicatus,* and *C. flexuosus.* This group includes about 1750 specimens from Barneveld strata.

Several other conodont groups are apparent in Trenton Group collections but are not named because they are, in general, known from fewer specimens than the above named groups, and do not appear to be of as much value in stratigraphic work at the present time.

Ligonodina tortilis and *Prioniodina macrodentata* are similar in basal cavity development and in the nature of process denticulation and seem to occur together in Barneveld strata. About 150 specimens occur in a ratio of one *L. tortilis* to about four *P. macrodentata.* This ratio of occurrence is similar to the ratio of 1:4.5 found for these species in the Pratt Ferry Formation of Alabama (Sweet & Bergström, 1962).

Scolopodus insculptus and *Paltodus dissimilaris* are simple cones whose union as a conodont group is based in part on similar morphology. *Scolopodus insculptus* is a bilaterally symmetric form with two costae on each side of the cusp. As Branson & Mehl (1933) noted, *Phragmodus (=Paltodus) dissimilaris* is like *S. insculptus* except that the two costae are only developed on one side of the cusp. About 45 specimens are referred to this group, with *S. insculptus* about 10 times as abundant as *Paltodus dissimilaris.*

Coelocerodontus trigonius and *C. tetragonius* are found together and are represented by about 80 specimens in the Barneveld. In addition, the color of these two species is different from other conodonts. Other conodonts are brown to dark gray or amber whereas specimens of *Coelocerodontus* are usually a light gray to white. This distinctive color is usually found in *Coelocerodontus* independent of the color of the other conodonts in the collection. Thus it is probably not a product of unusual localized weathering and may indicate a slight difference in composition. *Coelocerodontus* also seems different from other conodonts in its mode of growth; this is discussed under the genus.

Ambalodus elegans and *A. pulcher* are sporadically present in the Barneveld and seem to occur together. About 50 specimens are present with *A. elegans* about twice as common as *A. pulcher.*

Acodus inornatus and *Distacodus procerus* regularly occur together and are represented by about 150 specimens. For every three specimens of *A. inornatus,* there are two of *D. procerus.* In addition, these simple cones are quite similar morphologically to each other.

Belodina inclinata and *B. ornata* differ only in the placement of a lateral groove. Thus it can be suggested that they should be combined in one species. However, the ontogeny and variation cannot be determined in the small collection at hand (25 specimens), and thus they are grouped only on the basis of common occurrence.

More than 6,500 specimens of *Panderodus,* distributed unequally among four species, are present in the Trenton Group. All four species occur together in large collections and future work may indicate that these represent only one species. *P. striatus* and *P. arcuatus* are by far the most abundant, *P. compressa* is occasionally present, and *P. feulneri* was found only rarely and was confined to the Barneveld.

Drepanodus suberectus, Oistodus inclinatus, and remaining species of *Drepanodus* present in the Trenton Group are common long-ranging species. They do not seem to occur in any particular numerical ratio although *D. suberectus* and *O. inclinatus* are not nearly as abundantly represented as other species of *Drepanodus,* here grouped as *Drepanodus* spp. Nearly 4,000 specimens of these species were recognized. Until the systematics of Middle and Upper Ordovician *Drepanodus* is better known, the associates cannot be determined with any precision.

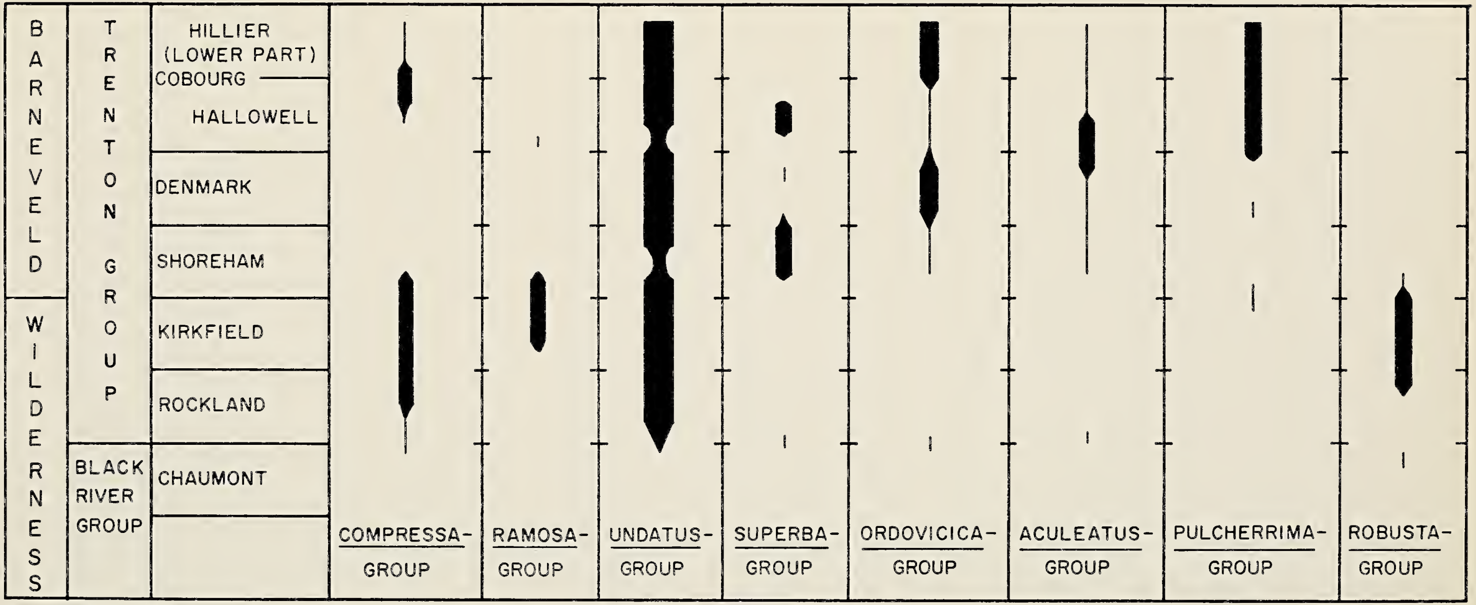


FIGURE 4. Distribution of some conodont peak zones in Trenton Group and equivalent strata, New York, Ontario, and Quebec. Explanation of conodont-groups is given in text. The width of the blackened area is a rough measure of relative abundance.

Oistodus pseudoabundans and *Phragmodus cognitus* perhaps occur together, but specimens were few, and much of the *Phragmodus* material is fragmentary, thus making identification difficult. In addition, one may suggest by analogy with the *undatus*-groups, that a species or two of *Dichognathus* would be present to accompany them. No other species of *Dichognathus* were recognized in the Trenton Group than those previously referred to the *undatus*-group.

Acodus aff. *A. unicostatus* and *Distacodus trigonius* have a similar basal cavity development and occur together in some samples. However, these species are known from only 35 specimens and thus their association is not certain.

Species that appear to occur without any faunal associates include *Holodontus superbus, Goniodontus superbus, Rosagnathus delicata, Oistodus venustus,* and *Trichonodella? tricurva.* Remaining species of the Trenton Group are generally represented by few specimens and no stand is taken as to their possible associates, if any. These include *Distacodus falcatus, Amorphognathus tvaerensis, Acontiodus? curvus, A. falcatus?, Acodus similaris, A. numaltipes, Belodina dispansa,* and *B. diminutiva.*

Late Wilderness and Barneveld conodonts belong to North American midcontinent and European (= Anglo-Scandinavian of Sweet *et al.,* 1959) faunas. This division provides a unifying theme in constructing Middle and Upper Ordovician conodont faunal development.

Midcontinent conodonts belong to the *undatus-, compressa-, ramosa-, robusta-,* and *pulcherrima*-groups (figure 4). These conodont groups characterize virtually every reported Middle and Upper Ordovician conodont collection from the North American midcontinent. In addition, during this time, no verified representatives of the *undatus*-group have been reported in Welsh or Swedish faunas, whereas representatives of this group constitute 50 percent or more of conodont collections from many midcontinent localities.

The European fauna includes, among others, the *aculeatus-, ordovicica-,* and *superba*-groups, and *Rosagnathus,* and *Holodontus.* All of these except the *superba*-group are represented in Welsh and/or Swedish deposits that are considered to be of the same or an earlier age as the deposits in which they occur in the Trenton Group. The earliest occurrence of the *superba*-group in the Welsh sequence is the Middle Caradocian Longvillian (Bergström, 1964), whereas representatives of it occur in the lowermost part of the Rockland Formation in New York and Ontario, and in the uppermost Chaumont Formation, Ottawa Valley (Barnes, pers. comm., 1964), which are here considered lower Caradocian Harnegian and/or Costonian (figure 5). However, in Trenton Group rocks, the occurrence and range of species assigned to the *superba*-group is like that of better established European conodonts, and so they are grouped with the European fauna.

What factors influence the sporadic distribution of conodonts shown in figure 4 and table 3? The problem of disjunct distribution is not confined by any means to conodonts (Flower, 1957, for example, cites cases for nautiloids and trilobites), and perhaps can best be explained in terms of changing broadly-based ecologic factors. The Shoreham faunal change was from particular types of trilobites, brachiopods, conodonts, and bryozoans to others within these same biologic groups. Thus the controlling ecologic factors differed in degree and not at levels threatening the support of life. That is, the distribution of each fauna was controlled by several of the following factors whose values were at least in part different for water masses containing each fauna: temperature, salinity, solar radiation, oxygen, and nutrients. In addition, the newly introduced trilobites (Cryptolithids) and conodonts are known from deposits of older age in Great Britain. The change in faunas thus is probably due to an ecologically induced faunal migration.

A modern ocean is a composite of several bodies of water which may have distinctive faunal differences. It may be the case that a lateral shift in water masses that were moving parallel to the Ordovician Appalachian geosynclinal region and the North American continental platform brought into the Black River Valley area a different fauna. This might be similar to the effect that would be caused by a continual lateral shift of the modern Gulf Stream. Different faunas would have different spatial distributions. If this suggestion is reasonable, then one would expect to be able to correlate more easily faunal sequences at various places along the strike of the currents than perpendicular to the strike. It is, in fact, easier to correlate the Middle Ordovician rocks of the New York and Cincinnati areas than it is to correlate either of these areas with Middle Ordovician rocks of the Upper Mississippi Valley.

If this general explanation of water type controlled faunas is adhered to, then one must assume that these water masses were less distinct faunally by the late Barneveld because of the high number of both European and midcontinent conodonts that occur together in the Cobourg.

Early Wilderness Fauna.—Early Wilderness, i.e., conodonts from the Black River Group, Shadow Lake, Gull River, and lower member of the Bobcaygeon Formations, were collected in parts of five sections (figure 3, locs. 1, 6, 10, 11, 13) and the conodont distribution is summarized in tables 4-6. "Fibrous" genera characterize this interval. Non-fibrous genera present include species of *Belodina, Panderodus, Trichonodella, Ozarkodina,* and *Cordylodus.* Unquestioned representatives of the *undatus*-group have not been collected from below the uppermost Chaumont.

Late Wilderness Fauna.—Deposits of late Wilderness age include the Rockland and Kirkfield Formations in New York and the middle and upper members of the Bobcaygeon Formation in Ontario. These deposits yielded conodonts at nine localities (figure 3, locs. 1, 2, 4, 6, 7, 10-12, 14) and their distribution is summarized in tables 4-6. Lowermost Rockland conodonts from three localities (figure 3, locs. 4, 10, 11) have definite European affinities. Present are representatives of the *superba-, ordovicica-,* and *aculeatus*-groups, and *Rosagnathus.* This is the earliest reported occurrence of these fossils in North America. European conodonts reappear in the study area in Shoreham beds and they characterize the conodont fauna of much of the Barneveld.

Conodonts of late Wilderness age are dominated by the *undatus*- and *compressa*-groups; the *ramosa*-group is common from the middle Kirkfield to the middle Shoreham.

Panderodus is represented in the late Wilderness fauna by small- to medium-sized specimens of *P. striatus, P. arcuatus,* and *P. compressus. Trichonodella? tricurva* is characteristic of the latest Wilderness — earliest Barneveld in Ontario, although a specimen of it is present in undescribed Ohio State collections made by the author from the uppermost Coburn Limestone, a Denmark-Cobourg equivalent (Kay, 1963) in central Pennsylvania.

"Fibrous" conodonts, rare in the late Wilderness, have been found in probable lower Kirkfield beds at four localities (figure 3, locs. 1, 2, 10, 14). At the Kirkfield Quarry (figure 3, loc. 14), they were found in beds that previously yielded *Gonioceras* (Dr. G. M. Kay, pers. comm., 1962), a nautiloid which, like fibrous conodonts, was common in the early Wilderness (Black River) and rare in the late Wilderness.

Barneveld Fauna.—Barneveld conodonts were recovered from nine localities (figure 3, locs. 1-5, 7-9, 14), and their distribution is recorded in tables 7-9. The Wilderness — Barneveld faunal break occurs within the Trenton Group. It occurs in an interval about 10 feet thick in the two sections (figure 3, locs. 2, 4) that cross this boundary (table 7) and is suggested in the very topmost beds at locality 7. The most significant changes are the disappearance of the *compressa-* and *ramosa*-groups and the rapid influx of representatives of the *ordovicica-, superba-,* and *aculeatus*-groups and *Rosagnathus.* These European conodonts are found in varying degrees in nearly all type area Barneveld conodont collections.

Mid-Shoreham through Cobourg limestones are divided tentatively into a sequence of five peak zones (figure 4). The middle and upper Shoreham contain the first of two peak zones of the *superba*-group except at City Brook (figure 3, loc. 2) in which European elements do not occur until the upper Shoreham and in which the *superba*-group has not yet been found. The lower to middle Denmark represents the lower of two peak zones of the *ordovicica*-group. The third peak zone is in the upper Denmark to lower Hallowell interval and is characterized by the *aculeatus*-group. In addition, the first occurrence of abundant representatives of the *pulcherrima*-group and large numbers of robust specimens of *Panderodus* are found in this interval.

In the lower Hallowell, the *superba*-group, as well as the *compressa*-group, recurs in the Deer River and Roaring Brook-Atwater Creek sections (figure 3, loc. 7, 4-5) but not at Trenton Falls (figure 3, loc. 3). A collection from the Hallowell of Galloo Island, near Watertown, New York, donated by Dr. R. L. Ethington, contained one nearly complete representative of *Polyplacognathus ramosa* in addition to the typical Hallowell assemblage. One fragment of this species was found in the Hallowell Member at Atwater Creek (figure 3, loc. 9), and both species of the *ramosa*-group are abundantly represented in the author's collections from the upper part of the Coburn Limestone, a suggested Denmark-Cobourg equivalent (Kay, 1963) of central Pennsylvania. In the lower to (?) middle Hillier, the *ordovicica*-group is represented by a second peak zone. Middle (?) and upper Hillier deposits are not believed to be represented in the sections studied and their fauna is not yet known.

As noted above, the southern sections, at City Brook and Trenton Falls, lack certain elements typical of other sections. Kay (1942b) has postulated a flexure or arch trending southwest in the vicinity of the City Brook section. This may have restricted faunal movements in these southern localities.

Local Correlation

Correlation of beds exposed at the Kirkfield quarry, Ontario (figure 2, loc. 14), and those at Hull, Quebec (figure 2, loc. 12), and the appropriate term to apply to post-Rockland, pre-Shoreham rocks in New York has been in question (Kay, 1937, 1953; Sinclair 1954). Kay believes that beds at Kirkfield in central Ontario, those referred to the Hull Formation in the Ottawa Valley, and the post-Rockland —pre-Shoreham rocks of New York are essentially contemporaneous. Sinclair suggests that beds at Kirkfield are older than beds called Hull in the Ottawa Valley, and correlates the Kirkfield exposures with the Rockland Formation.

The conodont succession in the type Rockland is in all important respects like that from beds called Rockland in New York (tables 5, 6). The conodont succession at the Kirkfield quarry is very similar to that found in the middle Kirkfield to lower Shoreham interval in New York and includes the late Wilderness fauna (table 6). Thus, beds at Kirkfield, now included in the Bobcaygeon Formation (Liberty, 1955, 1964), are correlated with the Kirkfield Formation in New York and seem definitely younger than beds exposed in the type section of the Rockland Formation.

At present it is not easy to determine the age of the Hull Formation in the Ottawa Valley in part, at least, because it is not certain which beds to call Hull. Raymond (1914) named the Hull but did not designate a type section. He did, however, discuss the units exposed in the 120-foot deep cement quarry at Hull, Quebec, in which he said that there were Hull beds exposed at the top, Black River beds 90 feet below the surface, and thus including a complete Rockland section in between. However, Sinclair (in Uyeno, 1963), places the upper 90 feet of this section in the lower Hull and the 30 feet exposed below this in the Rockland. Barnes (pers. comm., 1964) from a study of Middle Ordovician stratigraphy in the Ottawa Valley, suggests that beds of the upper few feet of the quarry lithologically resemble the lower Shoreham and that the remainder of the quarry lies within the Hull. Until the Ottawa Valley is mapped in

BRITISH GRAPTOLITE ZONE	BRITISH SERIES	BRITISH STAGE	SWEDISH AND ESTONIAN SERIES	SWEDISH AND ESTONIAN STAGE	AMERICAN STAGE		NEW YORK		CINCINNATI REGION	UPPER MISSISSIPPI VALLEY
PLEURO-GRAPTUS LINEARIS	CARADOCIAN	PUSGILLIAN	HARJUAN	VASAGAARD	? BARNEVELD		TRENTON GROUP	HILLIER	?	?
								COBOURG HALLOWELL	EDEN	DUBUQUE
DICRANO-GRAPTUS CLINGANI		ONNIAN ACTONIAN	VIRUAN ↓	OANDU				DENMARK	CYNTHIANA	STEWARTVILLE
		MARSHBROOKIAN LONGVILLIAN		KEILA				SHOREHAM	LEXINGTON	PROSSER
DIPLO-GRAPTUS MULTIDENS		SOUDLEYAN		JÕHVI	WILDERNESS ↓	LATE		KIRKFIELD		
		HARNEGIAN		IDAVERE				ROCKLAND		DECORAH
NEMA-GRAPTUS GRACILIS		COSTONIAN		KUKRUSE		EARLY	BLACK RIVER GROUP ↓	CHAUMONT	OREGON-TYRONE	PLATTEVILLE
								?	?	?

FIGURE 5. Correlation of the Trenton Group.

detail, the lateral relations of lithologic units evidently will be in doubt.

Conodonts were collected from the Hull Cement quarry at 10 and 61 feet above the quarry base and at four levels in the upper 30 feet of exposure in order to determine the age of the rocks. Collections are not large (table 6) ; however, all but the uppermost three samples contain the *compressa*-group, all but the upper two samples contain the *ramosa*-group and all contain specimens of the *undatus*-groups. The association of these conodont-groups characterizes the middle Kirkfield to lower Shoreham interval in New York. Thus it may present a major faunal anomaly if conodonts from the Hull Quarry are found to be in Rockland and/or Black River beds as Raymond and Sinclair suggested. On the other hand, formational names may not have been accurately applied to quarry units.

A problem related to the age of Kirkfield-Hull units is the correlation of the Coboconck beds of southern Ontario. Beds previously referred to the Coboconck Formation are now considered to be in the lower member of the Bobcaygeon Formation (Liberty, 1955, 1964). These rocks have been considered correlative with the Rockland Formation (Kay, 1937, 1942b). The Coboconck has also been considered correlative with the Chaumont Formation of the upper Black River, with the possibility that the upper few feet of the Coboconck type section could be correlative with the Rockland (Okulitch, 1939; Liberty, 1964).

The conodont succession of the type Coboconck (table 6) is characterized by the persistent presence of fibrous forms and the absence of *undatus*-group members, thus suggesting an age more probably equivalent to the Chaumont.

Regional Correlation

North America.—A summary of some North American and European correlations of the Trenton Group is shown in figure 5. Sub-Trenton Black River and sub-Lexington Oregon-Tyrone beds (Sweet & Rust, 1962) characteristically contain fibrous species. Distinctive late Wilderness — early Barneveld conodonts occur in New York in the Rockland through lower Shoreham interval, in Ohio and Kentucky in the lower part of the Lexington Group (Sweet & Rust, 1962), and in the Upper Mississippi Valley in the Decorah Formation (Stauffer, 1935b).

European conodonts first occur commonly in the Shoreham in New York. These conodonts also occur in the middle part of the Lexington Group (Sweet & Rust, 1962; Dr. W. C. Sweet, pers. comm., 1964). Ethington (1959) records the European *aculeatus*-group from the Prosser Member of the Galena Formation. The persistent occurrence of the European fauna permits correlation of the mid-Shoreham, to the mid-Lexington, and, possibly, to the lower Prosser.

The Denmark, and especially the Cobourg Formations, which succeed the Shoreham in New York, have a mixed midcontinent-European fauna in which European conodonts are almost always present but with changing characteristic conodont-groups. In general, however, continuity of faunal elements upward from the Shoreham faunal break prevails.

The post-Lexington Cynthiana and Eden Formations of the Cincinnati region have the same interplay of midcontinent and European elements (Sweet *et al.,* 1959; Drs. W. C. Sweet & S. M. Bergström, pers. comm., 1964, based on work in progress on this interval at Ohio State University). The base of the Eden Formation is marked by occurrence of members of the *compressa*- and *superba*-groups (Sweet *et al.,* 1959). This association also occurs in the lower part of the lower Cobourg, Hallowell Member, and is the first persistent appearance of these faunal elements since the mid-Shoreham. On the basis of this similarity in the sequence of conodont faunal changes, the lower Eden and lower Hallowell are correlated.

Correlation of the Fulton Shale (basal Eden) with the Holland Patent Shale, which rests on and is very likely laterally equivalent to lower Cobourg rocks according to the regional facies development (Kay, 1953), has been suggested on the basis of graptolites (Raymond, 1916). The Holland Patent contains the upper Caradocian guide fossil *Pleurograptus linearis* (Ruedemann, 1912, 1947). Hence the basal Eden and part of the Hallowell Member are upper Caradocian. Additional evidence of correspondence of the Eden and Hallowell was reviewed by Flower (1957) in the case of the trilobite, *Triarthrus eatoni.*

Forty-six of 48 conodont species present in the Galena Formation of Iowa (Ethington, 1959) are recognized in the Barneveld. Only *Acontiodus alveolaris* and *Panderodus panderi* are not yet known in New York. European species increase in number in the Stewartville and are best represented in the Dubuque. As stated above, the Decorah is correlated with the Rockland-Kirkfield. If the Prosser is correlated with the Shoreham, then the Stewartville and Dubuque could be time-equivalents of the Denmark and Cobourg. If the Hallowell and Eden are at least in part equivalent, then the European conodonts appear to have been especially widespread during this part of the upper Barneveld and thus could be correlated with the climax of European species in the Dubuque. The upper Eden and post-Eden Fairview and McMillan beds seem to have few European forms (Sweet *et al.,* 1959; Pulse & Sweet, 1960). European conodonts, however, continue to characterize remaining sampled Cobourg deposits. As noted above, European forms are present in the Rockland, but do not appear in the Cincinnati area until the mid-Lexington, and are not abundant in Iowa until the Dubuque. Evidently European conodonts did not dominate the faunas everywhere at the same time, and they persisted more regularly near the continental platform margin than on the craton. Knowledge of the Middle and Upper Ordovician conodont sequence of the Escanaba Peninsula, Michigan, could help considerably in determining migration routes as well as aiding correlation of the Upper Mississippi Valley sequence with that in New York.

The correlation of Eden and Cobourg strata suggested by conodont evidence supports in general that offered by Flower (1957) and Sinclair (1958, 1964). Kay suggested in 1935 that the Stewartville is equivalent to the upper Cobourg. Recently, Kay (1963) placed it opposite the Denmark; this latter correlation is supported here. As Kay (1960) noted, the conodont fauna of the Dubuque and Eden are quite similar. The explanation accepted here is that the Eden and Dubuque are at least in part correlative. Kay, however, (1937, 1960, 1963) continues to consider the Eden equivalent to post-Utica beds. For reasons given above, the Eden is correlated with part of the Dubuque and of the lower Cobourg, Hallowell Member. Thus, there is the possibility that the upper Cobourg, Hillier Member, and superjacent Utica Group beds are equivalent to the uppermost Eden and some part of the Maysvillian Stage.

Europe.—Correlation of the Trenton Group with the type Caradocian of Wales is facilitated by the recent study of Bergström (1964). Welsh conodont faunas are characterized by European species, and the typical midcontinent *undatus*-group of the Wilderness has not yet been recognized in the Welsh sequence. New York strata are correlated with known Welsh upper Longvillian and Marshbrookian faunas of the Pen-y-Garnedd, Gelli-grin and Crug Limestones because of similar phylogenetic development of specimens referred to *Rosagnathus delicata* and by the near total identity of the Welsh faunas with Barneveld conodonts.

Based on the revised faunal lists of Welsh faunas by Bergström (1964), 27 of 30 definitely identified species of the Gelli-grin and Pen-y-Garnedd are present in the Barneveld. Only *Amorphognathus complicata, Panderodus acostatus,* and *P. similaris* are not recognized in the Barneveld. Two tentatively identified species do not seem present in New York; these are *Drepanodus? altipes?* and *Trichonodella subundulata?*. Two representatives of generically questioned taxa are not recognized in New York; these are *Bryantodina?* sp., and *Oistodus?* sp. *A. complicata* seems a variation of *A. ordovicica* and the *Panderodus* species are not particularly distinctive. *T. subundulata* may be a growth stage of another species of *Trichonodella.* Thus, of these omissions, the most important is considered to be *Drepanodus? altipes?.*

Twenty-two of 24 definitely identified Crug Limestone conodont species are present in the Barneveld. Only *Spathognathodus pseudofissilis* and *Prioniodus? variabilis* are not recognized in New York. Five questionably or generically identified taxa do not seem present in the Barneveld; these are *Cordylodus* sp., *Oistodus* sp., *Hindeodella?* sp., *Oistodus?* sp., and *Trichonodella subundulata?*. The most significant absences from Barneveld collections are considered to be *Spathognathodus pseudofissilis* and *Prioniodus? variabilis.* The correlation of British stages based on shelly faunas with the graptolite sequence is from Dean (1958, 1962).

The youngest Swedish Middle Ordovician fauna yet reported is from that part of the Lower Caradocian Dalby (=Ludibundus) Limestone (Bergström, 1961) that represents the Idavere and Jõhvi stages (Jaanusson, 1960). The late Wilderness New York fauna could be at about the same stratigraphic level but its fauna is typically midcontinent in aspect and is not easily compared with the Dalby European fauna. Correlation and new terminology of Swedish and Estonian stages are from Jaanusson (1960a, 1960b, 1963).

Systematic Paleontology

Systematic Descriptions

Descriptive terminology is that used by Lindström (1955a) with the change that upper and lower are used in place of oral and aboral.

Genus ACODUS Pander, 1856

Type species: *A. erectus* Pander, 1856

ACODUS INORNATUS Ethington

Pl. 5, figure 20; figure 7-a.

Acodus inornatus ETHINGTON, 1959, p. 268, pl. 30, figure 11.

REMARKS.—*Acodus inornatus* mainly differs from *Distacodus procerus* in having an upper surface half to one-third as long and a correspondingly shorter basal cavity. *A. inornatus* tends to be bowed and to have its cusp recurved more quickly so that the lower third of the anterior margin may appear to be rounded. *D. procerus* is not bowed and the lower third of the anterior margin is straight. Some few specimens are referred to *A. inornatus* that have clearly defined costae symmetrically placed on each side of the cusp. The basal cavity and upper edge of these specimens is as in typical representatives of *A. inornatus.* The alternative to expanding the scope of *A. inornatus,* and by implication *Acodus,* is to define a new species of *Distacodus.* Importance is given by the author to general outline and character of the basal cavity; surface sculpture is considered of less basic taxonomic value.

TYPES.—Figured plesiotypes, NYSM 11691, 11770; six unfigured plesiotypes, NYSM 11692-11694.

ACODUS NUMALTIPES Schopf, n. sp.

Pl. 5, figure 17; figure 7-c, d, e.

Drepanodus? altipes Henningsmoen? SWEET *et al.*, 1959, p. 1048-1049, pl. 130, figure 1.

DIAGNOSIS.—A robust species of *Acodus* with long base, and deep conical basal cavity that extends to point of greatest curvature; asymmetry results from laterally expanded, rounded carina, prominent in lower half of element, and slight inward twisting of cusp distally.

DESCRIPTION.—Asymmetric simple cones with base laterally expanded on inner side, flat to slightly convex on outer side, and cusp rotated about 80° upward from upper surface. Anterior edge with sharp keel that is almost one-third the width of the element in the central part below the point of greatest cusp curvature; posterior edge weakly keeled. Basal cavity occupies unkeeled area of base, opens posteriorly, points anteriorly. Cusp twisted slightly inward distally, and symmetrical in cross-section. Entire unit finely striated longitudinally.

REMARKS.—Trenton representatives of *Acodus numaltipes* are like the specimen tentatively referred by Sweet *et al.* (1959) to *Drepanodus altipes* Henningsmoen, with which they have been directly compared. Specimens that Rhodes (1953) referred to *D. altipes* have also been examined; however, their lateral faces are gently convex and the whole unit is nearly bilaterally symmetrical, as in typical representatives of *Drepanodus*.

The type of *Drepanodus altipes* Henningsmoen is crushed, embedded in shale, and only one side is visible. Bergström (1964) has a drawing of this specimen, and it appears to lack the pronounced anterior keel typical of *Acodus numaltipes.* The long base, deep basal cavity, and lack of a lateral costa serve to distinguish *A. numaltipes* from the type of *Acodus, A. erectus* Pander.

TYPES.—Figured holotype, NYSM 11695; three unfigured paratypes, NYSM 11696-11697.

ACODUS SIMILARIS Rhodes
Pl. 5, figure 29.

Acodus similaris RHODES, 1955, p. 124-125, pl. 10, figures 7, 10, 14, 16, 18, 23, 27-28; ?26, ?30; LINDSTRÖM, 1959, p. 435, pl. 3, figures 6-7; BERGSTRÖM, 1964, p. 8-9, text-figure 1.

Drepanodus arcuatus RHODES, 1953, p. 292, pl. 21, figure 110.

REMARKS.—Trenton specimens referred to *Acodus similaris* are distinguished from similar species of *Acodus* and *Distacodus* in having a deep straight-sided basal cavity that occupies most of the cusp and has its apex near the cusp tip. One lateral face is evenly rounded; near the posterior margin of the other is a prominent longitudinal costa just anterior to which is a groove that opens posteriorly.

Distacodus procerus Ethington can be distinguished from *Acodus similaris* Rhodes in that the former is strongly compressed laterally and has well developed anterior and posterior keels, whereas the latter is only moderately compressed laterally and has weakly developed keels. The basal cavity of *A. similaris* is two or three times as deep as that of *D. procerus.* Two specimens shown by Rhodes (1955, pl. 10, figures 26, 30) appear to have the pronounced posterior keel typical of *D. procerus,* hence are herein only tentatively included in *A. similaris.*

TYPES.—Figured plesiotype, NYSM 11698; three unfigured plesiotypes, NYSM 11699.

ACODUS sp., aff. A. UNICOSTATUS Branson & Branson
Pl. 5, figure 18.

aff. *Acodus unicostatus* BRANSON & BRANSON, 1947, p. 554, pl. 82, figures 9, 10, 41, 43.

DESCRIPTION.—Asymmetric simple cones with rounded anterior and sharp posterior edges; inner lateral face flat to concave in central and posterior parts, with wide, rounded, anteriorly-placed carina; outer lateral face gently convex, somewhat flatter near posterior border. Slight indication of incipient denticulation perpendicular to posterior edge at mid-height.

Basal cavity deep and extends above the level of the upper surface and beyond point of greatest curvature; triangular in lateral view; anterior edge parallel to anterior cusp margin; posterior edge slightly concave and extends across unit to meet anterior edge near anterior margin of cusp; apex directed upward.

REMARKS.—The expanded inner lateral carina of mature specimens of *Acodus* aff. *A. unicostatus* may appear as a weak costa in juvenile forms. In having a rounded rather than keeled anterior margin and a lateral carina rather than a costa, it differs from typical *A. unicostatus.* However, the variation which may be ascribed to *A. unicostatus* has not yet been determined.

TYPES.—Figured plesiotype, NYSM 11700; four unfigured plesiotypes, NYSM 11701-11703.

Genus ACONTIODUS Pander, 1856

Type species: *A. latus* Pander, 1856

Both *Acontiodus* and *Distacodus* include simple cones with only two lateral costae. The four features that have been emphasized in distinguishing them are: (1) concave posterior face (Pander, 1856); (2) posterior placement of lateral costae (Lindström, 1955); (3) presence of symmetry; and (4) the arrangement of costae and intervening faces (Sweet & Bergström, 1962).

Pander and Lindström referred symmetrical forms to both genera. The type of *Acontiodus* is symmetrical and that of *Distacodus* is nearly symmetrical. Hence symmetrical forms may be referred to either genus.

The arrangement of costae and intervening faces generally is important, but it is equally important to know the shape of the intervening faces. A decision as to the circumscription of *Acontiodus* and *Distacodus* is based mainly upon whether one regards cusp cross-section shape or costal placement as the more important character.

Most can agree that forms with a concave or flat posterior face bounded by costae may be referred to *Acontiodus.* The question of generic assignment arises in the case of laterally compressed species, such as Ethington's (1959) *Distacodus procerus,* in which the only indication of a posterior face is a shallow groove just posterior to the lateral costae, and which have a prominent posterior keel. The author is of the opinion that *Distacodus* should include the laterally compressed species whose only indication of a posterior face is a shallow groove situated just posterior to the costae. Emphasis is placed on whether the cone is compressed or depressed rather than on whether the lateral costae are placed posteriorly.

Acontiodus herein includes simple, symmetrical, or subsymmetrical conodonts with smooth lateral faces, a well-developed nearly flat or concave posterior face that is keeled in most species, and to each side of which is a lateral costa located at the postero-lateral corner.

ACONTIODUS FALCATUS Ethington?
Pl. 5, figure 16.

?*Acontiodus falcatus* ETHINGTON, 1959, p. 268-269, pl. 39, figures 6, 7.

REMARKS.—Trenton specimens referred to *A. falcatus* are sharply notched in the lower lateral margin, a feature typical of *A. alveolaris* Stauffer. *A. alveolaris,* however, has a mid-posterior groove whereas all Trenton specimens have a mid-posterior costa, a feature diagnostic of *A. falcatus.* Trenton specimens are referred to *A. falcatus* because cusp cross-section shape is considered more important than lateral outline shape. It is possible that additional material would support recognition of Trenton forms as a distinct species intermediate between *A. falcatus* and *A. alveolaris* Stauffer, or that all those forms would be considered as "ornament groups" of the same species. It seems best not to deal with the homonymy with *A. falcatus* Hadding until additional material is available to settle the question of the limits of *A. falcatus* Ethington.

TYPES.—Figured plesiotype, NYSM 11704; one unfigured plesiotype, NYSM 11705.

ACONTIODUS? CURVUS Schopf, n. sp.
Pl. 5, figures 5, 6, 7; figure 6-a, b, c.

DIAGNOSIS.—A small simple conodont with an *Acontiodus*-like cross-section proximally, and anterior and posterior keels twisted relative to the base distally. Basal cavity is low and conical, with apex directed anteriorly.

DESCRIPTION.—The small, simple cones are symmetric to subsymmetric proximally and asymmetric distally. Element is laterally compressed with anterior and posterior keels. Lateral faces with

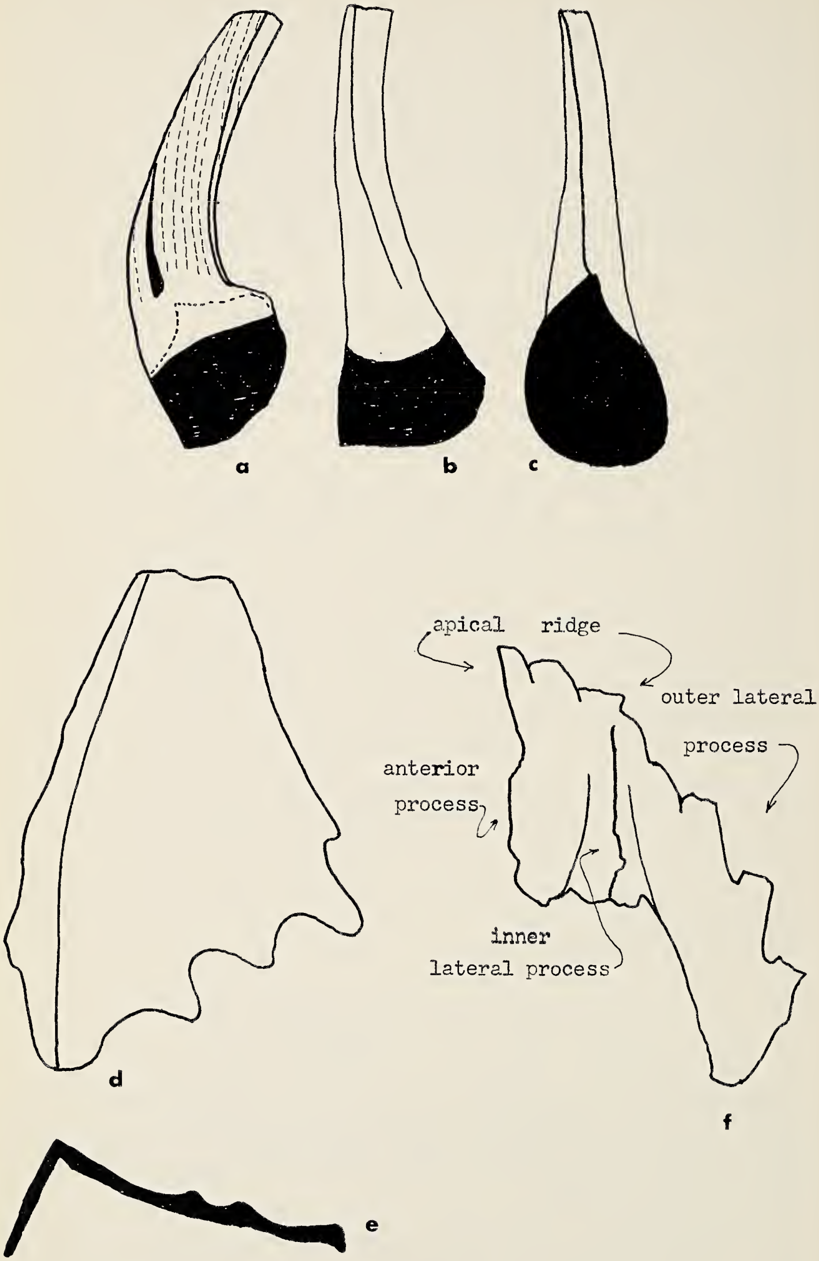

a
b
c
d
apical ridge
outer lateral
process
anterior
process
inner
lateral process
f
e

FIGURE 6

costae present proximally at postero-lateral corners. Posterior face is nearly flat except for mid-posterior keel. The whole unit has longitudinal striations.

Base is slightly expanded posteriorly with rounded upper surface. The basal cavity is shallow and triangular in lateral view; its upper margin is straight, directed anteriorly and slightly upward; its posterior margin is slightly concave and directed upward. All Trenton specimens have an empty basal funnel continuous with the conodont base; basal funnel free margin is entire.

Variation is especially prominent in cross-sections of the proximal anterior margin. In some specimens, the two sloping lateral faces meet at the anterior keel; in others, there is a rather broad anterior face on which is superimposed the anterior keel. However, overall shape and morphology of the basal cavity appear constant, and all of the specimens at hand are placed in one species.

REMARKS.—*Acontiodus? curvus* is tentatively referred to *Acontiodus* because the characteristic *Acontiodus* cross-section does not persist throughout the full length and, to some extent, the longitudinal striations could be considered costae, which would place this species in *Scolopodus*. In addition, *A.? curvus* might be considered representative of *Paltodus*, but the *Acontiodus-like* cross-section of the proximal part of the cusp is considered more important than distal alterations.

A.? curvus is similar proximally to *A. gracilis* reported by Ethington & Clark (1964) and *A. rectus* Lindström, but these species are not twisted distally. In lateral view, *A.? curvus* bears a resemblance to *Drepanodus striatus* Graves & Ellison and to *Scolopodus filosus* Ethington & Clark; however, the basal cavity of these species is said to be deep and thus quite different from *A.? curvus*.

TYPES.—Figured holotype, NYSM 11706; figured paratypes, NYSM 11707-11708; three unfigured paratypes, NYSM 11709-11710.

EXPLANATION OF FIGURE 6

Outline drawings of some Trenton conodonts. All are made from camera lucida drawings at X90.

Figures a, b, c—*Acontiodus? curvus* Schopf, n. sp. Lateral, anterior, and posterior views of paratype. Note longitudinal, spiral striations shown in Figure a. 62B-TR-141. NYSM 11708.

d, e—Dorsal septum and portion of dorsal valve of inarticulate brachiopod. 62B-CB-105. NYSM 11744.

f—*Holodontus superbus* Rhodes. Posterior view of plesiotype. 62B-TR-57. NYSM 11796.

Genus AMBALODUS Branson & Mehl, 1933
Type species: *A. triangularis,* Branson & Mehl, 1933

AMBALODUS ELEGANS (Rhodes)
Pl. 4, figure 11.

Ambolodus elegans RHODES, 1953, p. 278-279, pl. 20, figures 21-25.

Ambalodus elegans LINDSTRÖM, 1959, p. 435, pl. 3, figures 20-22; BERGSTRÖM, 1964, p. 11, text-figure 3.

Ambolodus robustus RHODES, 1953, p. 279-280, pl. 20, figures 26, 27, 32, 33.

?*Ambolodus* cf. *elegans* LINDSTRÖM, 1957, p. 172, pl. 1, figure 21, text-figure 2.

?*Ambalodus elegans* SWEET et al., 1959, p. 1040, pl. 132, figure 9.

REMARKS.—In the collection of *A. elegans* at hand, lateral process denticles are present in some specimens, absent in others, and inconspicuous in most. Considered together, a completely transitional series occurs from inconspicuously to well denticulated forms.

In general outline, *Ambalodus elegans* is like *Prioniodus alatus* Hadding. Each species seems to exhibit development of a platform on the inner side of the posterior process. However, *A. elegans* differs from *P. alatus* in having a broader anterior process, with two longitudinal ridges, the denticulated one of which continues as a costa to the denticle immediately anterior to the cusp. In *P. alatus,* a compressed anterior process bears one row of highly compressed denticles, which continues as a costa onto the cusp.

TYPES.—Figured plesiotype, NYSM 11711; three unifigured plesiotypes, NYSM 11712.

AMBALODUS PULCHER (Rhodes)
Pl. 4, figure 12.

Ambolodus pulcher RHODES, 1953, p. 279, pl. 20, figures 38-41.

Ambalodus pulcher LINDSTRÖM, 1959, p. 435, pl. 3, figures 14-16; BERGSTRÖM, 1964, p. 11, text-figure 4.

Prioniodus sp. SWEET *et al.,* 1959, p. 1061-1062, pl. 132, figure 8.

REMARKS.—The anterior process of *A. pulcher* is bowed so that its distal end is directed posteriorly. The outer, lateral process, is blade-like and crowned by a series of compressed denticles.

TYPES.—Figured plesiotype, NYSM 11713; three unfigured plesiotypes, NYSM 11714.

AMBALODUS TRIANGULARIS Branson & Mehl
Pl. 4, figures 1, 2, 3, 4, 5.

Ambalodus triangularis BRANSON & MEHL, 1933, p. 128, pl. 10, figures 35-37; GRAVES & ELLISON, 1941, p. 25, pl. 3, figures 29, 33-35; GLENISTER, 1957, p. 722, pl. 88, figures 20, 21; STONE & FURNISH, 1959, p. 219-220, pl. 32, figure 3; ETHINGTON, 1959, p. 269, pl. 40, figure 12; LINDSTRÖM, 1959, p. 435-436, pl. 2, figures 1-11; SWEET *et al.,* 1959, p. 1040, pl. 133, figure 4; PULSE & SWEET, 1960, p. 248, pl. 35, figure 16.

Ambolodus triangularis RHODES, 1953, p. 280, pl. 20, figures 28-31; RHODES, 1955, p. 122-123, pl. 7, figures 9-14.

Ambalodus triangularis ssp. *erraticus* BERGSTRÖM, 1961, p. 26-27, pl. 3, figures 15-17.

Ambalodus triangularis ssp. *suecicus* BERGSTRÖM, 1961, p. 28-29, pl. 3, figures 11-14.

Ambolodus triangularis var. *indentatus* RHODES, 1953, p. 280-281, pl. 20, figures 35-37, 56.

Dichognathus protexus STAUFFER, 1940, p. 422, pl. 59, figures 45, 46.

?*Ambolodus* sp. RHODES, 1953, p. 281, pl. 22, figures 171, 203.

REMARKS.—As here understood, *Ambalodus triangularis* is a quite variable species characterized by a prominent cusp, denticulate anterior and posterior processes developed as platforms, and a denticulate outer lateral process that is characteristically platform-like. In most specimens the outer lateral process bears a row of uncompressed denticles, or a ridge.

Both subspecies recognized by Bergström are present in Trenton material. Rhodes' *Ambolodus triangularis* var. *indentatus* is not a distinctive form variant in Trenton material.

A few Trenton specimens of *A. triangularis* are very robust and have as many as 15 laterally confluent denticles on the anterior process. The six denticles immediately anterior to the cusp are rather small; these are followed by a series of larger denticles, the middle few of which are the largest on the process. The last few denticles on the process diminish in size distally. Denticles of other processes are not developed differently from their usual manner.

TYPES.—Figured plesiotypes, NYSM 11715-11717; 23 unfigured plesiotypes, NYSM 11718-11719.

Genus AMORPHOGNATHUS Branson & Mehl, 1933
Type species: *A. ordovicica* Branson & Mehl, 1933

The narrow process of the main axis is anterior, and lateral processes are antero-lateral and postero-lateral.

AMORPHOGNATHUS ORDOVICICA Branson & Mehl
Pl. 3, figures 1, 2, 3, 4, 5, 6, 7.

Amorphognathus ordovicica BRANSON & MEHL, 1933, p. 127, pl. 10, figure 38; GRAVES & ELLISON, 1941, p. 25, pl. 3, figures 32, 36-38; RHODES, 1953, p. 283, pl. 20, figures 47-49; RHODES, 1955, p. 123, pl. 9, figure 4; STONE & FURNISH, 1959, p. 220, pl. 32, figure 12; PULSE & SWEET, 1960, p. 248-249, pl. 37, figures 13, 15; (The lateral projection of the specimen shown in figure 13 is an artifact of ammonium-chloride coating); BERGSTRÖM, 1961, p. 32-34; BERGSTRÖM, 1964, p. 15-17, text-figure 5.

Amorphognathus ordovicica simplicior BERGSTRÖM, 1961, p. 34-35, pl. 4, figures 2, 5, 6.

Amorphognathus ordovicica simplicior var. ? BERGSTRÖM, 1961, p. 35, pl. 4, figures 1, 3, 4.

Amorphognathus cf. *ordovicica* LINDSTRÖM, 1959, p. 436-437, pl. 2, figures 12-17.

Amorphognathus aff. *A. duftona* ETHINGTON, 1959, p. 270-271, pl. 40, figure 11.

Amorphognathus sp. LINDSTRÖM, 1959, p. 437-438, pl. 2, figures 18, 19.

Balognathus expansa RHODES, 1953, p. 285, pl. 20, figures 50-53, 57.

?*Amorphognathus duftonus* RHODES, 1955, p. 123-124, pl. 9, figures 1, 3, 5, 8.

REMARKS.—Two "ornament-groups" of *Amorphognathus ordovicica* occur in Trenton material. In the non-blade type, the main denticle row is laterally confluent, while in the blade type, it increases in size from the anterior end of the process and reaches its greatest development in a spike located just anterior to the central area in which denticles are absent or weakly developed (terminology consistent with Bergström, 1964).

In upper view with the anterior process directed upward, the non-blade form seems only to occur in specimens which have the large postero-lateral process on the left and the small antero-lateral process on the right. Oriented in the same way, the blade form has the large postero-lateral process on the right and the small antero-lateral process on the left. This suggests sinistral and dextral specimens. In lateral view, non-blade forms are strongly arched whereas blade forms are not arched.

Blade and non-blade forms have similarly developed lateral processes. The postero-lateral process is expanded at its junction with the main denticle row. The process is bilobed with the anterior lobe invariably better developed than the posterior lobe. The bilobed antero-lateral process is reduced in width at its junction with the main denticle row. Its posterior lobe is somewhat more robust than the anterior lobe. A shelf is developed on the lateral margin of many specimens. This is more pronounced on the flatter blade specimens than on the arched non-blade specimens but is present in both types.

The author has examined the type of *Balognathus expansa* and found the same evidence of its identity with *Amorphognathus ordovicica* as did Lindström (1959) and Bergström (1961, 1964).

TYPES.—Figured plesiotypes, NYSM 11720-11724; ten unfigured plesiotypes, NYSM 11725-11726.

AMORPHOGNATHUS TVAERENSIS Bergström
Pl. 3, figures 8, 9.

Amorphognathus tvaerensis BERGSTRÖM, 1961, p. 36-37, pl. 4, figures 7-10.

REMARKS.—Two Trenton representatives of *Amorphognathus* have three lateral processes that join the main denticle row in the same relative places as those of the types of *A. tvaerensis* and thus are referred to that species. They are about half as large as two Ludibundus Limestone topotypes in Ohio State University collections with which they have been compared directly. Blade and non-blade types with reversed configuration are distinguished in the same manner as in *A. ordovicica*. Both Trenton specimens are of the non-blade type.

TYPES.—Figured plesiotypes, NYSM 11727-11728.

Genus BELODINA Ethington, 1959, in Stone & Furnish, 1959
Type species: *Belodus compressus* Branson & Mehl, 1933

BELODINA COMPRESSA (Branson & Mehl)
Pl. 1, figures 1, 3, 4, 6.

Belodus compressus BRANSON & MEHL, 1933, p. 114, pl. 9, figures 15, 16; MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 9, 10.

Belodina compressa SWEET *et al.*, 1959, p. 1042-1044, pl. 133, figures 12, 15; CARLSON, 1960, p. 77, pl. 2, figure 19.

Belodus grandis Stauffer, 1935b, p. 603-604, pl. 72, figures 46, 47, 49, 53, 54, 57.

Belodina grandis Ethington, 1959, p. 272, pl. 40, figure 14; Sweet & Bergström, 1962, p. 1224, pl. 170, figures 16, 17.

Belodus wykoffensis Stauffer, 1935b, p. 604, pl. 72, figures 51, 52, 55, 58, 59.

Belodina wykoffensis Ethington, 1959, p. 272-273, pl. 40, figure 16.

Belodina inclinata? Pulse & Sweet, 1960, p. 250-251, pl. 37, figures 10, 11.

Belodus sp. Mehl & Strothmann, in Branson, 1944, p. 81, pl. 12, figures 7, 8.

?*Belodus wykoffensis* Graves & Ellison, 1941, p. 25, pl. 3, figure 26.

?*Belodina compressa* Stone & Furnish, 1959, p. 220, pl. 31, figure 14.

?*Belodus compressus*? Furnish, Barragy & Miller, 1936, p. 1336, 1338, pl. 1, figure 10, pl. 2, figure 13.

Specimens typically referred to *B. grandis* are longer than high, and have a cusp that is continuously rounded apically, anterior denticles that are proclined, and, in most specimens, a pronounced ridge along and parallel to the outer lower margin; those specimens referred to *B. compressa* are shorter than high, and have a sharp cusp and erect denticles. Of the characters that can distinguish *B. grandis* and *B. compressa,* only the height to length ratio seems to be of constant value. That is, denticle inclination is probably a function of whether or not the unit is extended antero-posteriorly; also, in large representatives of *B. compressa,* the typically sharp cusp envelops denticles immediately posterior to it, and is rounded. These two "ornament groups" are considered representative of a rather broadly defined species.

TYPES.—Figured plesiotypes, NYSM 11729-11732; 14 unfigured plesiotypes, NYSM 11733.

BELODINA DIMINUTIVA (Branson & Mehl)
Pl. 1, figures 5, 8, 12.

Belodus diminutivus Branson & Mehl, 1933, p. 125, pl. 10, figure 27.

Belodus ornatus Glenister, 1957 (part), p. 730-731, pl. 87, figure 7, (not pl. 87, figures 9, 10).

REMARKS.—Specimens referred to *Belodina diminutiva* are higher than long and have a smooth inclined inner face, and a grooved flat outer face. The basal cavity is crimped but not separated entirely for its full length, and extends to the anterior end of the upper margin denticle row. Several small specimens at hand (example in Pl. 1, figure 5) are like larger specimens referred to this species in curvature, basal cavity, and groove on the flat outer face. However, these specimens lack fully-developed denticles. It appears that full denticle development is a characteristic of mature forms in *B. diminutiva,* although a completely transitional growth series could not be shown in the limited material at hand.

TYPES.—Figured plesiotypes, NYSM 11734-11736.

BELODINA DISPANSA (Glenister)

Pl. 1, figure 7.

Belodus dispansus GLENISTER, 1957, p. 729-730, pl. 88, figures 14, 15.

Belodina dispansa STONE & FURNISH, 1959, p. 220-221, pl. 31, figure 11; ETHINGTON & FURNISH, 1959, p. 542, pl. 73, figures 12, 13.

Belodina aff. *dispansa* ETHINGTON, 1959, p. 272, pl. 40, figure 15.

REMARKS.—Diagnostic of this species is the upper margin which bears a series of small, proclined denticles, rather than the series of large, discrete, peg-like denticles characteristic of other species of *Belodina.* A rather wide variety of forms exhibiting the diagnostic serrate margin are here grouped as one species. Variation exists in degree of development of the serrate margin, curvature, and cross section.

TYPES.—Figured plesiotype, NYSM 11737; four unfigured plesiotypes, NYSM 11738.

BELODINA INCLINATA (Branson & Mehl)

Pl. 1, figures 2, 9.

Belodus inclinatus BRANSON & MEHL, 1933, p. 125-126, pl. 10, figure 24.

Belodus ornatus GLENISTER, 1957 (part), p. 730-731, pl. 87, figure 10, (not pl. 87, figures 7, 9).

Belodina inclinata ETHINGTON & FURNISH, 1960, p. 269, pl. 38, figure 13.

REMARKS.—Specimens referred to *Belodina inclinata* are longer than high, and are quite asymmetric with a grooved flat outer face, and a smooth inclined inner face.

TYPES.—Figured plesiotypes, NYSM 11739-11740; five unfigured plesiotypes, NYSM 11741-11742.

BELODINA ORNATA (Branson & Mehl)
Pl. 1, figure 11.

Belodus ornatus BRANSON & MEHL, 1933, p. 124-125, pl. 10, figures 26, 28; GLENISTER, 1957 (part), p. 730-731, pl. 87, figure 9, (not pl. 87, figures 7, 10).

REMARKS.—Specimens referred to *Belodina ornata* are longer than high and have a smooth flat outer face, and an inclined grooved inner face.

TYPE.—Figured plesiotype, NYSM 11743.

Genus BRYANTODINA Stauffer, 1935
Type species: *B. typicalis* Stauffer, 1935

BRYANTODINA ABRUPTA (Branson & Mehl)
Pl. 4, figures 13, 14.

Ozarkodina (?) *abrupta* BRANSON & MEHL, 1933, p. 100, pl. 6, figure 11.

Bryantodina sp. MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 34-36.

REMARKS.—There seem to be two variants of *Bryantodina* represented in the specimens at hand; these are referred to *B. abrupta* because it does not appear that they could be kept apart in large material. The first type (Pl. 4, figure 14) is characterized by a steeply inclined cusp, short posterior process, and an anterior process that increases in height distally. The second type (Pl. 4, figure 13) has a less steeply inclined cusp and in most specimens a slightly longer posterior process than the first type; the anterior process is about the same height over its total length. These two types seem to be about equally well represented.

The specimen figured by Hinde (1879) as *Prioniodina? politus* is probably a *Bryantodina*. The type, which is embedded in a siltstone, was studied and found to be an extremely mature specimen. It is distinguished from forms here referred to *B. abrupta* by its more nearly erect cusp, and longer posterior process (which is not complete). The specimen that Rhodes (1953) referred to *Bryantodina* n. sp. also has a more erect cusp and has less regular anterior process dentition than specimens referred to *B. abrupta*.

TYPES.—Figured plesiotypes, NYSM 11745-11746; 12 unfigured plesiotypes, NYSM 11747-11748.

Genus COELOCERODONTUS Ethington, 1959
Type species: *C. trigonius* Ethington, 1959

Coelocerodontus was erected for simple conodonts whose basal cavity extends to the tip of the element and whose walls are exceedingly thin. These conodonts are unlike other simple cones because of the continuously thin nature of the wall from base to tip. That is, each lamella was deposited over exactly the same area as preceding lamellae and there was no change in basal cavity size or position relative to the rest of the element during growth.

COELOCERODONTUS TETRAGONIUS Ethington
Pl. 5, figure 8.

Coelocerodontus tetragonius ETHINGTON, 1959, p. 273, pl. 39, figure 15.

TYPES.—Figured plesiotype, NYSM 11749; one unfigured plesiotype, NYSM 11750.

COELOGERODONTUS TRIGONIUS Ethington
Pl. 5, figure 9.

Coelocerodontus trigonius ETHINTON, 1959, p. 273, pl. 39, figure 14.

TYPES.—Figured plesiotype, NYSM 11751; six unfigured plesiotypes, NYSM 11752.

Genus CORDYLODUS Pander, 1856
Type species: *C. angulatus* Pander, 1856

CORDYLODUS DELICATUS Branson & Mehl
Pl. 2, figures 22, 23; ?24, 25, 26, 27.

Cordylodus (?) *delicatus* BRANSON & MEHL, 1933, p. 129, pl. 10, figures 14, 15; GRAVES & ELLISON, 1941, p. 25, pl. 3, figure 23; GLENISTER, 1957, p. 731-732, pl. 88, figure 5.

Cordylodus delicatus SWEET *et al.*, 1959, p. 1044-1045, pl. 132, figures 12, 14, 17; PULSE & SWEET, 1960, p. 251, pl. 36, figures 4, 7; BERGSTRÖM, 1964, p. 18-21, text-figures 6, 7.

Subcordylodus delicatus MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 17, 18; ETHINGTON, 1959, p. 288, pl. 41, figure 13.

Plectodina tilbara STAUFFER, 1940, p. 429, pl. 59, figures 50, 57, 58, 64.

Subcordylodus rectilineatus STAUFFER, 1935a, p. 154, 160, pl. 11, figures 30, 32.

Cordylodus rectilineatus RHODES, 1953, p. 300-301, pl. 22, figures 172-175.

Cordylodus elongatus RHODES, 1953, p. 299-300, pl. 21, figures 114-118; 1955, p. 135, pl. 7, figures 5, 6.

Cordylodus geniculatus RHODES, 1953, p. 300, pl. 21, figure 113.

Cordylodus cf. *spurius* LINDSTRÖM, 1959 (part), p. 438, pl. 4, figures 19, 20 (not pl. 4, figure 21).

?*Prioniodus cristulus* STAUFFER, 1930, p. 128, pl. 10, figure 19.

DESCRIPTION.—Specimens referred to *Cordylodus delicatus* have in common a prominent cusp, a bowed posterior process set with closely spaced compressed denticles that are erect to slightly reclined, and a basal cavity whose apex points anteriorly and upward and which penetrates only to the bottom of the cusp. In some exceptionally large specimens that are tentatively referred to *C. delicatus,* denticles are developed along the inner margin of the downward extension of the cusp.

REMARKS.—*Cordylodus delicatus* is distinguished from *C. serratus* Stauffer (= *C. rectilineatus* of authors) by (1) evenly spaced, basally confluent denticles, rather than basally discrete denticles that become larger and increasingly more widely spaced distally; (2) an anterior edge that is recurved anteriorly in its lower part, rather than one that is continuously curved posteriorly; (3) *C. delicatus* is bowed whereas *C. serratus* is in the same vertical plane. In contrast to both of these species, typical representatives of *C. elongatus* (Stauffer) have a posterior process that is strongly laterally sinous.

Some very robust specimens (Pl. 2, figures 24-27), which closely resemble *Eoligonodina* Branson, Mehl, & Branson, are here tentatively referred to *Cordylodus delicatus.* They are like typical representatives of that species in all particulars except for their great size and the presence of denticles along the inner anterior cusp margin. Small specimens with these distinctive features have not been found, and in the material at hand it is probable that the development of cusp edge denticles is a part of the normal development in very robust *C. delicatus.* Such specimens are very few, however, and an unequivocal decision cannot be made.

TYPES.—Figured plesiotypes, NYSM 11753-11758.

CORDYLODUS FLEXUOSUS (Branson & Mehl)
Pl. 2, figure 20.

Prioniodus (?) *flexuosus* BRANSON & MEHL, 1933, p. 130, pl. 10, figure 16.

Cordylodus flexuosus SWEET *et al.*, 1959, p. 1045, pl. 132, figure 13; PULSE & SWEET, 1960, p. 251-252, pl. 36, figures 6, 9; BERGSTRÖM, 1964, p. 17-18.

Cyrtoniodus complicatus STAUFFER, 1935a, p. 140, pl. 11, figures 44, 46, 48-51; STAUFFER, 1935b, p. 604, pl. 73, figures 9, 11-13, 15, 16, 18-20, 25, 27, 32, 38, 41, 42, 47; RHODES, 1953, p. 302, pl. 22, figures 193-196; GLENISTER, 1957, p. 732, pl. 88, figure 16; ETHINGTON, 1959, p. 274, pl. 40, figure 7; ETHINGTON & FURNISH, 1959, p. 546, pl. 73, figure 4; 1960, p. 270.

Cyrtoniodus apicalis STAUFFER, 1935b, p. 604, pl. 73, figures 1, 10, 43, 45.

Plectodina glenwoodensis STAUFFER, 1935a, p. 152, pl. 11, figures 38, 39.

?*Subcordylodus* sp. STAUFFER, 1935b, p. 618, pl. 73, figure 21.

Cordylodus? *spurius* RHODES, 1953, p. 301, pl. 21, figure 133.

Cordylodus cf. *spurius* LINDSTRÖM, 1959 (part) p. 438, pl. 4, figure 21 (not pl. 4, figure 19, 20).

?*Cyrtoniodus complicatus* SWEET, 1955, p. 254, pl. 28, figure 3.

?*Cordylodus* (?) *spurius* BRANSON & MEHL, 1933, p. 117, pl. 10, figure 4.

?*Euprioniodina crassa* STAUFFER, 1932, p. 262, pl. 40, figure 24.

?*Cyrtoniodus sinclairi* ETHINGTON & FURNISH, 1960, p. 270-271, pl. 38, figure 16.

DESCRIPTION.—Specimens referred to *Cordylodus flexuosus* have in common a prominent, laterally compressed cusp, slightly bowed posterior process with closely appressed denticles erect at the cusp and distally increasingly inclined, a prominent inner lateral flare at the base of the cusp, and a shallow basal cavity that does not extend into the cusp or denticles.

REMARKS.—*Cordylodus flexuosus* is similar to *C. typicalis* (Stauffer) from which it is differentiated by the presence of closely appressed, posteriorly inclined denticles, rather than widely spaced, erect denticles. Ethington & Furnish (1960) described *Cyrtoniodus sinclairi* as a development from robust specimens of *Cyrtoniodus complicatus* in which denticles are present on the downward projection of the cusp. Insofar as this may be normal gerontic development (see discussion under *Cordylodus delicatus*), *Cyrontiodus sinclairi* tentatively is placed in synonymy with *Cordylodus flexuosus.*

TYPE.—Figured plesiotype, NYSM 11759.

CORDYLODUS n. sp.
Pl. 2, figure 16.

DIAGNOSIS.—A species of *Cordylodus* in which the antero-basal corner is rounded, the cusp erect, the cusp base does not flare laterally, and with a very shallow basal cavity whose apex is situated posterior to the axis of the erect cusp in most specimens.

DESCRIPTION.—Conodonts referred to this species are sickle-shaped and consist of a compressed erect cusp, a bowed posterior process that is set with at least seven elliptical postero-upward and outward-directed basally separated denticles, and a shallow anteriorly directed basal cavity that opens posteriorly and extends as a shallow groove to the end of the process. The basal cavity does not extend under the cusp proper in most specimens but is present as a conical depression directed anteriorly into the downward extension of the cusp and process to a line approximately parallel to the posterior edge of the cusp. The process is bowed and slightly twisted so that the basal furrow under the process distally opens somewhat to the inner lateral side. The antero-basal corner is rounded.

REMARKS.—This species is close to *Cordylodus flexuosus* Branson & Mehl and *C. tenuis* Branson & Mehl but differs from them in its lack of a prominent inner lateral flare of the base and a much reduced basal cavity. *Cordylodus sp.* is closest to *C. typicalis* (Stauffer) and *C. grandis* (Stauffer) which were described from the Decorah Formation. However, the cusp of these species is bowed, and the basal cavity is deep. Insofar as specimens at hand are few and of a similar age to Stauffer's Decorah species, it seems best not to name them until the limits of variation are better known.

TYPE.—Figured specimen, NYSM 11760.

Genus DICHOGNATHUS Branson & Mehl, 1933

Type species: *Dichognathus prima* BRANSON & MEHL, 1933

Specimens of *Dichognathus* in Trenton collections, like those in previously described Middle and Upper Ordovician faunas (Branson & Mehl, 1933; Sweet *et al.*, 1959), form a continuous series in which the outer process angle varies from about 45° to about 10°. However, the end members that are here recognized, *D. brevis* and *D. typica,* are conspicuously different in cusp and process development in addition to the outer process angle difference, and thus both species are tentatively maintained. The stratigraphic range of each species in the Trenton Group seems the same, and so these are recorded on distribution tables as *Dichognathus* spp.

From an examination of the type of *Dichognathus* (?) *furcatus* Hinde, the author agrees with Bergström (1964) that it should be referred to *Prioniodina* because of the absence of an anterior flange on the cusp.

DICHOGNATHUS BREVIS Branson & Mehl

Pl. 1, figure 15.

Dichognathus brevis BRANSON & MEHL, 1933, p. 113, pl. 9, figures 24-26; SWEET, 1955, p. 258, pl. 28, figure 14; GLENISTER, 1957, p. 734, pl. 88, figures 10, 12; SWEET *et al.,* 1959, p. 1047, pl. 132, figure 7; PULSE & SWEET, 1960, p. 252, pl. 35, figures 9, 14.

Dichognathus decipiens BRANSON & MEHL, 1933, p. 99-100, pl. 6, figures 24, 25.

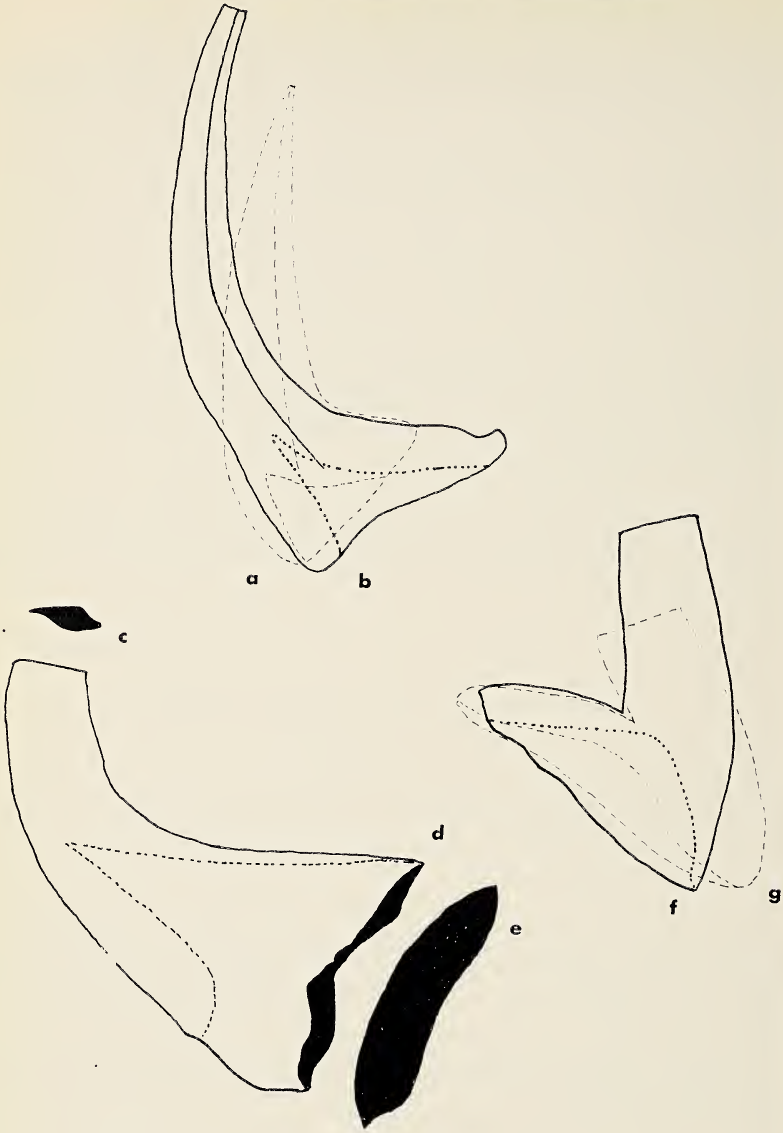
REMARKS.—Specimens referred to *Dichognathus brevis* have in common a relatively large cusp, short processes, and an outer process angle close to 45°.

TYPES.—Figured plesiotype, NYSM 11761; one unfigured plesiotype, NYSM 11762.

DICHOGNATHUS TYPICA Branson & Mehl

Pl. 1, figure 17.

Dichognathus typica BRANSON & MEHL, 1933, p. 113, pl. 9, figures 27-29; PULSE & SWEET, 1960, p. 252, pl. 37, figures 6, 14, with additional references through 1959.



EXPLANATION OF FIGURE 7

Outline drawings of some Trenton conodonts. All are made from camera lucida drawings at X90.

Figures a, b—*Acodus inornatus* Ethington; and *Distacodus procerus* Ethington. Lateral views of plesiotypes. 62B-K-7. NYSM 11770.

c, d, e—*Acodus numaltipes* Schopf, n. sp. Cusp cross section, lateral view, and basal cross section of holotype. 62B-TR-141. NYSM 11695.

f, g—*Oistodus abundans* Branson & Mehl; and *Oistodus pseudoabundans* Schopf, n. sp. Lateral views of plesiotype and paratype. 62B-K-2. NYSM 11812.

Dichognathus extensa BRANSON & MEHL, 1943, p. 387, pl. 64, figure 10; GLENISTER, p. 734, pl. 88, figures 11, 17; SWEET *et al.*, 1959, p. 1047-1048, pl. 132, figures 2, 3.

?*Dichognathus* cf. *typica* SANNEMANN, 1955, p. 25, pl. 2, figure 13.

?*Dichognathus typica* BERGSTRÖM, 1961, p. 37-38, pl. 5, figure 6.

not *Dichognathus* cf. *typica* RHODES, 1953, p. 317-318, pl. 22, figures 178-180.

REMARKS.—Specimens referred to *Dichognathus typica* have in common a relatively short cusp, long processes, and an outer process angle close to 20°.

TYPES.—Figured plesiotype, NYSM 11763; one unfigured plesiotype, NYSM 11764.

Genus DISTACODUS Pander, 1856
Type species: *Machairodus incurvus* Pander, 1856

Distacodus includes asymmetric to symmetric simple conodonts that lack a concave or posterior face and have anterior and posterior keels with a posterior costa on each lateral face.

DISTACODUS FALCATUS Stauffer
Pl. 5, figure 27.

Distacodus falcatus STAUFFER, 1935a, p. 142, pl. 12, figure 16; 1935b, p. 605, pl. 74, figure 30; ETHINGTON, 1959, p. 275, pl. 39, figure 9.

?*Scolopodus cornuformis* SERGEEVA, 1963, p. 93-95, pl. 7, figures 1-3, text-figure 1.

TYPES.—Figured plesiotype, NYSM 11765; eight unfigured plesiotypes, NYSM 11766-11768.

DISTACODUS PROCERUS Ethington
Pl. 5, figure 1; Figure 7-b.

Distacodus procerus ETHINGTON, 1959, p. 275, pl. 39, figure 8.

TYPES.—Figured plesiotypes, NYSM 11769-11770; four unfigured plesiotypes, NYSM 11771.

DISTACODUS? TRIGONIUS Schopf, n. sp.
Pl. 5, figures 2, 3, 4.

?*Paltodus* sp. WALLISER, 1957, p. 43, pl. 2, figures 7a, 7b.

DIAGNOSIS.—A subsymmetrical *Distacodus* with wide anterior face bounded by antero-lateral costae, slightly concave lateral faces, and a proximally developed posterior keel. Apex of basal cavity extends to point of greatest curvature; proximal cross-section is triangular.

DESCRIPTON.—Unit not quite symmetrical, for inner lateral face is more concave than outer lateral face, especially proximally. Anterior face flat; antero-lateral corners sharp in lower half and continue on cusp as antero-lateral costae. Lateral cusp faces are flat to slightly convex. A posterior keel is present proximally but disappears at point of greatest curvature; posterior cusp surface convex. Base deeply excavated; anterior edge and lateral faces of basal cavity parallel anterior edge of element and lateral faces; posterior face directed anteriorly and joins the anterior face at point of greatest curvature. Although the cusp is not complete in any specimen, the basal cavity might extend through about half the total length of the element.

REMARKS.—This species is referred to *Distacodus* with great hesitation because of the absence of a well defined anterior keel. In this regard it differs from the otherwise similar *D. rhombicus* Lindström and from the several species which Pander (1856) brought to *Machairodus (= Distacodus)*. However, the lateral costae, clearly defined posterior keel, and lack of a posterior face suggest *Distacodus* in preference to other simple cone genera. Walliser (1957) has interpreted what may be a conspecific form so as to include it in *Paltodus;* that is, one edge is picked as anterior; the specimen then has a posterior keel and a lateral rounded carina. Walliser noticed five thin costae along one of the lateral faces. Fine ornamentation is difficult to determine in the material at hand; however, the most striking feature of this species, its triangular cross-section in the lower part, is clearly visible in Trenton material and in Walliser's figure. Hence the tentative decision to refer Walliser's specimens to *Distacodus? trigonius.*

In Trenton Group collections, the affinities of *D.? trigonius* are with *Acodus* aff. *unicostatus* Branson & Branson in terms of basal cavity development, size, and occurrence. *A.* aff *unicostatus* is, however, a markedly unsymmetric unit with a prominent inner lateral carina whereas *D.? trigonius* is subsymmetric with slightly concave lateral faces.

TYPES.—Figured holotype, NYSM 11772; six unfigured paratypes, NYSM 11773-11775.

Genus Drepanodus Pander, 1856

Type species: *D. arcuatus* Pander, 1856

Pander (1856) based *Drepanodus* on material from Lower Ordovician rocks in Estonia and differentiated three species according to differences in cusp curvature. A fourth species, however, was erected for strongly arched specimens that are conspicuously keeled, and a fifth species includes stout, blunt-tipped specimens. The character of the basal cavity was not considered in specific determination.

Lindström (1955a) limited the genus to symmetrical or subsymmetrical simple conodonts with smooth lateral faces, sharp anterior and posterior edges, and a posterior cusp edge that meets the upper margin in a curve. With the exception of Glenister (1957), authors of Middle and Upper Ordovician conodont studies have rarely reported *Drepanodus* species other than *D. homocurvatus* and *D. suberectus*. The latitude given to *D. homocurvatus* is especially broad.

In Trenton collections, there are approximately 3,200 reclined simple cones referable to *Drepanodus*. The author attempted to subdivide them into species which, however, depended on virtually complete specimens for identification. Thus more than half the specimens were unidentified as to species, and all specimens were counted as *Drepanodus* spp. The more abundant types of reclined *Drepanodus* are distinguished in the following key.

Key to common reclined species of *Drepanodus* in Trenton collections:

1. Lower third of anterior margin perpendicular to extension of upper margin; posteriorly placed basal cavity with apex a little above half way between the upper margin and a line parallel to the upper margin passing through the antero-basal corner; anterior edge of basal cavity deeply notched ....
   Drepanodus planus Lindström
   If not so 2

2. Element bowed; anterior keel best developed near base but continues to mid-height; anterior margin depressed on inner side and, in lateral view, the keel is distinguishable only from inner side; basal cavity triangular in outline with anterior and upper surfaces straight and subequal in length; anterior edge of basal cavity subparallel through most of its length with anterior cusp edge ....
   cf. *Drepanodus homocurvatus* Lindström
   If not so 3
3. Anterior margin of basal cavity meets anterior or lower margin at 45°-75°; cusp slightly reclined; basal cavity apex almost as high as posterior edge of upper margin ....
   Drepanodus sp. cf. *D. arcuatus* of Lindström (1955a)
   If not so 4
4. Anterior margin of basal cavity meets anterior face at less than 45°; cusp moderately reclined; apex of basal cavity approximately half way between upper margin and a line parallel to upper margin passing through antero-basal corner; upper surface of basal cavity concavo-convex ....
   Drepanodus amoenus Lindström

Drepanodus amoenus Lindström
Pl. 5, figure 12.

Drepanodus amoenus Lindström, 1955a, p. 558, pl. 2, figures 25, 26, text-figure 4b; Ethington & Clark, 1964, p. 688, pl. 113, figure 5.

TYPE.—Figured plesiotype, NYSM 11776.

Drepanodus planus Lindström
Pl. 5, figure 21.

Drepanodus planus Lindström, 1955a, p. 565-566, pl. 2, figures 35-37, text-figure 4a.

TYPES.—Figured plesiotype, NYSM 11777; one unfigured plesiotype, NYSM 11778.

Drepanodus suberectus (Branson & Mehl)
Pl. 5, figure 25.

Oistodus suberectus BRANSON & MEHL, 1933, p. 111, pl. 9, figure 7; BRANSON, MEHL, & BRANSON, 1951, p. 8-9, pl. 2, figures 1-4.

Drepanodus suberectus SWEET & BERGSTRÖM, 1962, p. 1226, pl. 169, figure 8, with additional references through November, 1962; ETHINGTON & CLARK, 1964, p. 689-690, pl. 113, figure 18.

?*Drepanodus suberectus* SANNEMANN, 1955, p. 27, pl. 1, figure 22, pl. 2, figure 1.

REMARKS.—The basal cavity illustrated by Sannemann (1955, pl. 2, figure 1) is conical and much deeper than typical representatives of *Drepanodus suberectus.*

TYPES.—Figured plesiotype, NYSM 11779; one unfigured plesiotype, NYSM 11780.

DREPANODUS sp. cf. D. ARCUATUS of Lindström (1955) non Pander (1856)

Pl. 5, figure 13.

cf. *Drepanodus arcuatus* LINDSTRÖM, 1955a, p. 560-561, pl. 2, figures 45, 46, text-figure 4c.

TYPES.—Figured plesiotype, NYSM 11781; one unfigured plesiotype, NYSM 11782.

DREPANODUS sp. cf. D. HOMOCURVATUS Lindström

Pl. 5, figures 11, 14, 15.

cf. *Drepanodus homocurvatus* LINDSTRÖM, 1955a, p. 563, pl. 2, figures 23, 24, 39, text-figure 4d.

TYPES.—Figured plesiotypes, NYSM 11783-11785; two unfigured plesiotypes, NYSM 11786-11787.

Genus EOBELODINA Sweet, Turco, Warner, & Wilkie, 1959

Type species: *Oistodus fornicalus* Stauffer, 1935

EOBELODINA FORNICALA (Stauffer)

Pl. 1, figure 16.

Oistodus fornicalus STAUFFER, 1935b, p. 610, pl. 75, figures 3-6; ETHINGTON, 1959, p. 282, pl. 39, figure 19; CARLSON, 1960, p. 77, pl. 2, figure 18.

Eobelodina fornicala SWEET *et al.,* 1959, p. 1050-1051, pl. 133, figure 11.

Belodus (?) sp. MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 12, 13.

?*Oistodus fornicalus* GRAVES & ELLISON, 1941 (part), p. 17, pl. 1, figures 15, 17, (not pl. 2, figures 15, 18).

TYPES.—Figured plesiotype, NYSM 11788; 11 unfigured plesiotypes, NYSM 11789.

Genus FALODUS Lindstrom, 1955
Type species: *Oistodus prodentatus* Graves & Ellison, 1941

Eofalodus Harris, 1962, is considered congeneric with *Falodus* Lindström, 1955. The major feature differentiating these genera, according to Harris, is the presence of one rather than several denticles on the antero-basal margin of the cusp. Sweet (1963) notes as a general rule, and in this case in particular, that this difference is unreliable for generic distinctions, and the author agrees.

FALODUS PRODENTATUS Graves & Ellison
Pl. 3, figure 11.

Oistodus prodentatus GRAVES & ELLISON, 1941, p. 13, 14, pl. 2, figures 6, 22, 23, 28.

Oistodus breviconus MEHL & STROTHMANN, 1944, p. 90, pl. 13, figures 7, 8. For additional references see SWEET & BERGSTRÖM, 1962.

REMARKS.—A few Trenton specimens are like those referred by Mehl & Strothmann (1944) to *Oistodus breviconus* and either lack or have obscure denticles on the antero-basal margin of the cusp. Such specimens are in every other way comparable with typical representatives of *Falodus prodentatus.* Thus these undenticulate (?) specimens are referred to this species.

TYPES.—Figured plesiotype, NYSM 11790; 12 unfigured plesiotypes, NYSM 11791.

Genus GONIODONTUS Ethington, 1959
Type species: *G. superbus* Ethington, 1959

Goniodontus Ethington, 1959, is of the same structural plan as *Holodontus* Rhodes, 1953. Oriented in the same way, the posterior process of *Goniodontus* corresponds to the inner lateral process of *Holodontus;* the anterior outer basal process of *Goniodontus* corresponds to the outer lateral process of *Holodontus;* the anterior inner lateral process of *Goniodontus* is the anterior edge because the well-defined anterior process of *Holodontus* is absent in *Goniodontus.*

Goniodontus is herein maintained distinct from *Holodontus* despite their great overall similarity because the evolutionary development of *Goniodontus* is as yet uncertain, and it seems unwise to combine genera based on distinct species unless their evolutionary history is well known. In addition, *G. superbus* would be a homonym of *H. superbus,* and thus a possibly unnecessary name would have to be introduced.

GONIDONTUS SUPERBUS Ethington
Pl. 4, figure 18.

Goniodontus superbus ETHINGTON, 1959, p. 278, pl. 40, figures 1, 2.

REMARKS.—The species is characterized by one prominent and one secondary denticle on the apical ridge, the absence of an anterior process, an inner lateral process that is ridged and bears one (or more?) small denticles, and a denticulate outer lateral process. Small denticles are present between the two denticles of the apical ridge in small specimens; in larger specimens, these denticles are overgrown by lateral expansion of the main denticles and may appear as "germ denticles".

TYPES.—Figured plesiotype, NYSM 11792; six unfigured plesiotypes, NYSM 11793.

Genus HOLODONTUS Rhodes, 1953
Type species: *H. superbus* Rhodes, 1953

Holodontus includes paired, individually asymmetric, subpyramidal conodonts with two downwardly directed lateral processes and one anterior process, which are variously twisted and denticulated and are joined across the apex of the unit by a conspicuously denticulate apical ridge. A basal cavity is developed beneath each process and the apical ridge.

The orientation of *Holodontus* adopted here and shown diagrammatically in figure 6-f, is essentially that of Rhodes (1953), but, with respect to designation of inner and outer lateral processes, is opposite to Bergström's (1961) orientation of *Tvaerenognathus,* which he (1964) considered synonymous with *Holodontus.*

HOLODONTUS SUPERBUS Rhodes
Pl. 4, figures 16, 17; figure 6-f.

Holodontus superbus RHODES, 1953, p. 304, pl. 21, figures 125-127; BERGSTRÖM, 1964, p. 26-27, text-figure 11.

REMARKS.—Apical ridge with three prominent denticles, the central one of which is dominant in most specimens. Anterior process with only one denticle, which caps the process. Inner lateral process not denticulated, but with a prominent ridge on its upper surface which extends to the most posterior denticle of the apical ridge. Outer lateral process with widely spaced denticles.

TYPES.—Figured plesiotypes, NYSM 11794-11796; two unfigured plesiotypes, NYSM 11797-11798.

Genus ICRIODELLA Rhodes, 1953
Type species: *I. superba* Rhodes, 1953

ICRIODELLA SUPERBA Rhodes
Pl. 3, figures 17, 22, 23.

Icriodella superba RHODES, 1953, p. 288, pl. 20, figures 54, 58, 62, 63, 65, 78.

Icriodella superba var. *acuta* RHODES, 1953, p. 288, pl. 20, figures 59, 60, 64, 66, 71-73, 77.

Icriodella deforma RHODES, 1953, p. 286, pl. 20, figures 68-70.

Icriodella elongata RHODES, 1953, p. 287, pl. 20, figures 79-81.

Icriodella plana RHODES, 1953, p. 287, pl. 20, figures 67, 74, 76.

Icriodella acuta ETHINGTON, 1959, p. 279-280, pl. 41, figure 5.

Icriodella sp. RHODES, 1953, p. 288-289, pl. 20, figure 61.

REMARKS.—The types of Rhodes' (1953) five species and one variety have been examined. Taking into account the abraded appearance of the denticles and the fact that four species are monotypic, the variation exhibited falls within the range of variation of Trenton material referred to *Icriodella superba.* The better preserved Barneveld material shows that the platform-like process should be regarded as the anterior process, for the cusp is inclined away from this process. This is more apparent in younger growth stages.

TYPES.—Figured plesiotypes, NYSM 11799-11801; 15 unfigured plesiotypes, NYSM 11802-11803.

Genus LIGONODINA Bassler, 1925
Type species: *L. pectinata* Ulrich & Bassler, 1926

LIGONODINA TORTILIS Sweet & Bergström
Pl. 4, figures 22, 23, 26.

Ligonodina tortilis SWEET & BERGSTRÖM, 1962, p. 1230-1231, pl. 170, figures 13, 14.

REMARKS.—Specimens at hand agree in most respects with the type description and illustrations and with two Pratt Ferry topotypes in the collections of Ohio State University. In several Trenton specimens, however, the posterior process is directed laterally, rather than downward, as is the case in the Pratt Ferry types.

TYPES.—Figured plesiotypes, NYSM 11804-11805; eight unfigured plesiotypes, NYSM 11806-11807.

Genus OISTODUS Pander, 1856
Type species: *O. lanceolatus* Pander, 1856

OISTODUS ABUNDANS Branson & Mehl
Pl. 1, figures 10, 14; figure 7-f.

Oistodus abundans BRANSON & MEHL, 1933, p. 109, pl. 9, figures 11, 17; STAUFFER, 1935b (part), p. 609, pl. 75, figure 2 (not pl. 75, figures 7, 11-13, 19: =*Oistodus inclinatus*); Sweet *et al.*, 1959, p. 1052-1053, pl. 130, figure 3; Pulse & Sweet, 1960, p. 254-255, pl. 35, figures 1, 8.

Oistodus breviconus Branson & Mehl, 1933, p. 109-110, pl. 9, figures 13, ?14.

Oistodus abundans Stauffer, 1935a, p. 146, pl. 12, figure 22; 1940, p. 426, pl. 60, figure 20; Sannemann, 1955, p. 28, pl. 2, figure 8; Glenister, 1957, p. 725, pl. 86, figure 5; Ethington, 1959, p. 282, pl. 39, figure 21.

not *Oistodus abundans* Graves & Ellison, 1941, pl. 2, figures 19, 20; Branson & Mehl, 1943, p. 386, pl. 64, figure 11 (= *Oistodus inclinatus*); Rhodes, 1953, p. 294, pl. 21, figures 91, 92 (= *Oistodus venustus*?).

REMARKS.—Representatives of *Oistodus abundans* are distinguished by an inner lateral expansion of the base, an antero-basal angle of approximately 60°, and a reclined cusp.

The cusp of one of the two specimens referred to *Oistodus abundans* by Graves & Ellison (1941, pl. 2, figure 20) is parallel to the base; the other specimen (pl. 2, figure 19) has a narrow cusp that meets the upper surface at approximately a right angle. Specimens referred by Rhodes to *O. abundans* lack the inner lateral basal expansion.

The figured cotypes of *Oistodus breviconus* Branson & Mehl include one specimen (pl. 9, figure 13) which shows the diagnostic characters of *O. abundans.* The other specimen (pl. 9, figure 14), however, seems to have a regenerated cusp and a lateral bulge high on the base. It is certainly an unusual specimen, but could equally be regarded as 1.) a pathologic representative of *O. abundans,* or 2.) the type of a distinctive species. In order to ease future work with these forms, the specimen shown in Branson & Mehl's pl. 9, figure 13, is here designated lectotype. *O. breviconus* is thus a junior subjective synonym of *O. abundans.*

TYPES.—Figured plesiotypes, NYSM 11808-11809, 11812; two unfigured plesiotypes, NYSM 11810-11811.

Oistodus inclinatus Branson & Mehl

Pl. 5, figure 10.

Oistodus inclinatus Branson & Mehl, 1933, p. 110, pl. 9, figure 8; Stauffer, 1935a, p. 147, pl. 12, figure 21; Stauffer, 1935b, p. 610-611, pl. 75, figures 9, 14, ?pl. 74, figure 41; Furnish, Barragy, & Miller, 1936, p. 1336, 1338, pl. 1, figure 7, pl. 2, figure 19; Furnish, 1938, p. 330, pl. 41, figure 18; Graves & Ellison, 1941, p. 21, 25, pl. 2, figure 16, ?pl. 3, figure 18; Branson & Mehl, 1943, p. 386, pl. 64, figure 1; Branson, Mehl, & Branson, 1951, p. 5, pl. 2, figures 5, 6; Sannemann, 1955, p. 28, pl. 1, figures 23, 24; Stone &

FURNISH, 1959, p. 224, pl. 31, figure 6; SWEET *et al.,* 1959, p. 1053-1054, pl. 131, figure 6; PULSE & SWEET, 1960, p. 255, pl. 35, figures 10, 12; CARLSON, 1960, p. 76, pl. 2, figure 13.

Oistodus excelsus STAUFFER, 1935b, p. 610, pl. 74, figure 43; GLENISTER, 1957, p. 725-726, pl. 86, figures 4, 7; STONE & FURNISH, 1959, p. 224, pl. 31, figure 5; ETHINGTON, 1959, p. 282, pl. 39, figure 20; SWEET *et al.,* 1959, p. 1053, pl. 130, figure 5; WOLSKA, 1961, p. 351, pl. 3, figures 1a, 1b; BERGSTRÖM, 1961, p. 44, pl. 2, figures 18, 19.

Oistodus abundans STAUFFER, 1935b (part), p. 609, pl. 75, figures 7, 11-13, 19 (not pl. 75, figure 2: = *Oistodus abundans*); BRANSON & MEHL, 1943, p. 386, pl. 64, figure 11.

Oistodus cf. *inclinatus* LINDSTRÖM, 1959, p. 440, pl. 3, figure 10.

Oistodus sp. aff. *O. inclinatus* BERGTRÖM, 1961, p. 44-45, pl. 1, figure 16, text-figure 3J.

Oistodus sp. MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 1, 2.

?*Oistodus inclinatus* WOLSKA, 1961, p. 351-352, pl. 3, figures 2a, 2b.

?*Oistodus basiovalis* SERGEEVA, 1963, p. 96-98, pl. 7, figures 6, 7, text-figure 3.

REMARKS.—This species is commonly represented in most North American Middle and Upper Ordovician deposits. The original descriptions of *Oistodus inclinatus* by Branson & Mehl (1933) and *O. excelsus* by Stauffer (1935b) are very close. Branson & Mehl (1933) figured the outer side, whereas Stauffer (1935b) figured the inner side. The present author can see no way to keep these two forms apart in the large collection at hand.

Variation consists mainly of differences in cusp curvature, from straight to distally curved upward, and of differences in the upper surface — posterior cusp edge angle, which varies from sharply acute to nearly 90°. As a rule, the larger growth stages have a larger angle between the upper edge of the base and the posterior cusp edge.

TYPES.—Figured plesiotype, NYSM 11813; 31 unfigured plesiotypes, NYSM 11814-11815.

OISTODUS PSEUDOABUNDANS Schopf, n. sp.

Pl. 1, figure 13; figure 7-g.

DIAGNOSIS.—An *Oistodus* with a rounded antero-basal edge and a lower margin that is nearly straight. The basal cavity is shallow, and the cusp straight and reclined. The upper margin of the base is gently convex upward.

DESCRIPTION.—The basal cavity, which extends for the full length of the base, is narrow anteriorly and posteriorly, and slightly expanded laterally inward at mid-width. It is shallow and from four to six times longer than deep. The posterior basal expansion is long and thin, and the anterior extension short. Lower margin straight or nearly so.

Cusp laterally compressed, keeled anteriorly and posteriorly, carinate on inner side and reclined, and curved inward distally. The cusp is from one and one-half to two times the length of the base.

REMARKS.—*Oistodus pseudoabundans* is closely comparable to *O. abundans* Branson & Mehl, from which it differs in having a shallower and longer basal cavity and a more reclined cusp (figure 7-g). *O. pseudoabundans* differs most markedly from *O. venustus* Stauffer in having a nearly flat lower margin that continues in a straight line to the anterior edge rather than being obliquely truncated. *O. pseudoabundans* may be compared with *O. linguatus* and *O. selene* Lindström, from the Swedish Lower Ordovician, but representatives of those species have a deeper basal cavity. *O. pseudoabundans* also occurs in undescribed Ohio State research collections from the Platteville of Iowa.

TYPES.—Figured holotype, NYSM 11816; figured paratype, NYSM 11812; 18 unfigured paratypes, NYSM 11817-11819.

OISTODUS VENUSTUS Stauffer
Pl. 5, figure 19.

Oistodus venustus STAUFFER, 1935a, p. 147, pl. 12, figure 12.
?*Oistodus abundans* RHODES, 1953, p. 294, pl. 21, figures 91, 92.
For additional references see SWEET & BERGSTRÖM, 1962.

REMARKS.—Specimens here referred to *Oistodus venustus* are alike in having a bicarinate, sharp-edged cusp that is usually only slightly longer than the base. The basal cavity is long and shallow, and the postero-basal angle is about 75°. The upper margin is straight to slightly convex, but the lower margin is flexed upward at an angle of approximately 120° beneath the lateral flare of the base.

TYPES.—Figured plesiotype, NYSM 11820; six unfigured plesiotypes, NYSM 11821-11822.

Genus OZARKODINA Branson & Mehl, 1933
Type species: *O. typica* Branson & Mehl, 1933

OZARKODINA sp. cf. O. TENUIS Branson & Mehl
Pl. 2, figures 11, 12, 13.

cf. *Ozarkodina tenuis* BRANSON & MEHL, 1933, p. 128-129, pl. 10, figures 19-21, 23.

REMARKS.—Individual specimens closely resemble three of Stauffer's species, *Ozarkodina robusta, O. concinna,* and *O. pauperata,* Lindström's *O. rhodesi* and *O. pseudotypica,* and Branson & Mehl's *O. tenuis.* However, the correct interpretation of this group of species, as well as *O. inclinata* Glenister, *Aphelognathus irregularis* Pulse & Sweet, and related forms, is a complex problem whose solution mainly rests on studies of growth stages. Trenton material does not permit such a study, and the author has not seen most of the types involved. Thus all specimens are here compared with *O. tenuis,* which is the oldest name available for this group of Ozarkodinas.

There do appear, however, to be two different groups of species combined. The younger group is found almost exclusively in the Barneveld. In mature specimens (Pl. 2, figure 13) it is characterized by a lip along the lower margin that is especially pronounced in the central part. The lateral faces of the basal sheath become laterally expanded and rounded, again, especially in the central part beneath the cusp. The processes are subequal in length, the unit only gently arched, and denticles laterally compressed and usually basally to medially confluent. The basal cavity seems to be increasingly restricted to the central part of the element in more mature specimens. This form closely resembles *O. tenuis, O. pseudotypica, O. inclinata,* some figured specimens of Stauffer's closely related, if not identical, *O. robusta, O. concinna,* and *O. pauperata* and Ethington's *O. concinna* (1959, pl. 41, figure 15).

The older group is found almost exclusively in the Wilderness. In mature specimens (Pl. 2, figures 11, 12) it is characterized by an anterior process about twice the height of the posterior process, an elongate laterally bowed posterior process, denticles which tend to be discrete basally, especially on the posterior process, where they may also be somewhat rounded rather than compressed. The processes are more sharply arched, with an angle of about 140° between them. The basal cavity is sheathed throughout its extent and is not restricted in its development. This form is in certain respects like specimens Stauffer (1935b) referred to *Ozarkodina robusta* (cf. pl. 71, figure 4), and Rhodes (1953) referred to *O. tenuis*. In addition, it seems possible that at least one of Branson & Mehl's (1933) cotypes of *O. tenuis* (pl. 10, figure 19) could develop into this type of *Ozarkodina*.

TYPES.—Figured specimens, NYSM 11823-11825; 34 unfigured specimens, NYSM 11826-11830.

Genus Paltodus Pander, 1856
Type species: *P. subaequalis*, 1856

Paltodus dissimilaris (Branson & Mehl)
Pl. 3, figures 24, 25.

Phragmodus dissimilaris Branson & Mehl, 1933, p. 123-124, pl. 10, figure 29; Graves & Ellison, 1941, p. 24, pl. 3, figure 9.

REMARKS.—This species includes simple, unsymmetric multicostate conodonts, and so is referred to *Paltodus*.

TYPE.—Figured plesiotype, NYSM 11831.

Genus Panderodus Ethington, in Stone & Furnish, 1959
Type species: *Paltodus unicostatus* Branson & Mehl, 1933

Four species of *Panderodus* are recognized in Trenton strata. *P. striatus* (Stauffer) and *P. arcuatus* (Stauffer) are by far the most abundant; *P. compressus* (Branson & Mehl) is commonly represented, and *P. feulneri* (Glenister) is rare and has been found only in the Barneveld.

The types of *P. striatus* and *P. arcuatus* have been studied and are easily distinguished specimens. In Trenton collections, however, there are many specimens intermediate between the slightly unsymmetrical *P. striatus* and the markedly unsymmetrical *P. arcuatus*. Both names are here retained, however, because this group is in general poorly known, and it may be best to indicate more subdivisions at the present time than ultimately might prevail.

Originally the author had prepared extensive synonym lists for *Panderodus striatus* and *P. arcuatus*. However, as the work progressed, it became clear that it would be necessary to see types of several species in order to report accurately on the state of this group of conodonts. At this time, the author is inclined to regard the type specimens of *P. gracilis, P. intermedius, P. unicostatus,* and *P. arcuatus* in one group whose main distinguishing feature is the uneven development of lateral faces and hence marked unsymmetry. *P. staufferi, P. robustus,* and *P. striatus,* on the other hand, have more uniform development of lateral faces and tend to be only slightly unsymmetric. Some 6,500 specimens are referred to *Panderodus* spp.

PANDERODUS ARCUATUS (Stauffer)
Pl. 5, figures 26, 28.

Paltodus arcuatus STAUFFER, 1935b, p. 612, pl. 74, figures 6, 8, 9; MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 27-28.

DESCRIPTION.—Specimens here referred to *Panderodus arcuatus* are characterized by a marked unsymmetry that results from uneven development of lateral faces. The anterior margin is rounded, and the junction of anterior and inner lateral faces is marked by a costa which tends to be most prominent in earlier growth stages. In most specimens, the antero-outer lateral face junction is marked by a rounded shoulder and adjacent groove posterior to the shoulder. The outer lateral face is broadly rounded and not as wide as the characteristically flat to concave inner lateral face. The inner lateral face is subdivided longitudinally by a weakly developed groove. In most specimens, a bowed posterior costa extends from the base to high on the cusp.

TYPES.—Figured plesiotype, NYSM 11832; eight unfigured plesiotypes, NYSM 11833.

PANDERODUS COMPRESSUS (Branson & Mehl)
Pl. 5, figure 23.

Paltodus compressus BRANSON & MEHL, 1933, p. 109, pl. 8, figure 19; STAUFFER, 1935a, p. 150, pl. 12, figures 17, 26; BRANSON, MEHL, & BRANSON, 1951, p. 7, pl. 1, figures 16-22.

Panderodus compressus Ethington, 1959, p. 284, pl. 39, figure 4; Ethington & Furnish, 1959, p. 546, pl. 73, figure 8.

Paltodus cornutus Stauffer, 1935b, p. 612, pl. 74, figures 1, 2, 11, 13-15, 19; Stauffer, 1940, p. 427, pl. 60, figure 10.

DESCRIPTION.—Specimens here referred to *Panderodus compressus* are slightly unsymmetric, have a rounded anterior margin, and are strongly laterally compressed. The distance between the anterior margin and the anterior edge of the basal cavity is relatively great in this species. The junction of anterior and lateral faces is marked by low rounded shoulders followed posteriorly by a longitudinal groove. The outer lateral face is bisected by a prominent groove; the inner lateral face is bisected by a weakly developed groove. The posterior edge is keeled.

TYPES.—Figured plesiotype, NYSM 11834; three unfigured plesiotypes, NYSM 11835-11836.

Panderodus feulneri (Glenister)

Pl. 5, figure 30.

Paltodus feulneri Glenister, 1957, p. 728, pl. 85, figure 11.

TYPE.—Figured plesiotype, NYSM 11837.

Panderodus striatus (Stauffer)

Pl. 5, figures 22, 24.

Paltodus striatus Stauffer, 1935b, p. 613, pl. 74, figures 3, 16; Stauffer, 1940, p. 428, pl. 60, figures 5, 12, 13, 17.

Paltodus equicostatus Rhodes, 1953, p. 297, pl. 21, figures 106-109; pl. 22, figures 162, 165.

DESCRIPTION.—Slightly unsymmetric representatives of *Panderodus,* with broadly rounded anterior and narrowly rounded posterior edges; lateral faces developed about equally, with mid-width longitudinal groove more pronounced on one side than the other. Antero-lateral corners are rounded or sharply bent; most larger specimens have a more rounded antero-lateral margin than smaller specimens. In most specimens, a posterior costa extends from the base to high on the cusp; it is slightly bowed, thus accounting for the element's slight unsymmetry.

REMARKS.—A small proportion of specimens in most collections that are referred to *Panderodus striatus* are relatively longer, less wide, and less high than typical representatives of the species. Such specimens might represent an early growth stage of *P. striatus* or may fall within intraspecific variation of *P. panderi* (Stauffer).

TYPES.—Figured plesiotype, NYSM 11838; seven unfigured plesiotypes, NYSM 11839-11840.

Genus PERIODON HADDING, 1913

Type species: *P. aculeatus* Hadding, 1913

Periodon is considered distinct from *Phragmodus* because, in addition to the different appearance of typical representatives (reviewed by Sweet & Bergström, 1962), their faunal associates and characteristic areal distribution are separate. *Periodon aculeatus,* the only species of *Periodon,* is a typical European species which, when found in North America, is commonly associated with *Falodus prodentatus* and other European conodonts. *Phragmodus undatus* is a dominant element of United States midcontinent faunas and is associated with species of *Dichognathus* and *Oistodus.* Thus, *Periodon* and *Phragmodus* seem to have belonged to different organisms.

PERIODON ACULEATUS Hadding

Pl. 3, figures 10, 12, 13, 14, 16.

Periodon aculeatus HADDING, 1913, p. 33, pl. 1, figure 14.

Loxognathus flabellata GRAVES & ELLISON, 1941, p. 12, pl. 2, figures 29, 31, 32.

Loxognathus grandis ETHINGTON, 1959, p. 281, pl. 40, figure 6.

Trichondella insolita ETHINGTON, 1959, p. 289-290, pl. 41, figure 9.

For additional references see SWEET & BERGSTRÖM (1962).

REMARKS.—The commonly associated specimens here referred to *Periodon aculeatus* represent three distinct form-variants, each of which has a posterior process with typical *Periodon* denticulation, but differs in degree of development of denticulate cusp costae. This variation is similar to that exhibited by the three form-variants described for *Phragmodus undatus,* in which anterior, anterior and one lateral, or anterior and two lateral cusp costae, are variably developed (Sweet *et al.,* 1959; Pulse & Sweet, 1960).

Specimens referred to *Periodon aculeatus* by previous authors have a denticulate anterior costa deflected toward one side of the asymmetric cusp (pl. 3, figures 10, 14). Specimens assigned to *Loxognathus grandis* (Ethington, 1959) have a denticulate anterior costa that is deflected laterally and developed as a posteriorly extending process. On the cusp face opposite the one toward which the anterior process is deflected, a lateral costa is continuous with a downward-directed process (pl. 10, figure 12). Forms referred by Ethington to *Trichonodella insolita* have their two lateral cusp costae developed as posteriorly-directed processes, thus yielding a symmetric unit (pl. 10, figure 13).

TYPES.—Figured plesiotypes, NYSM 11841-11845; 17 unfigured plesiotypes. NYSM 11846-11850.

Genus PHRAGMODUS Branson & Mehl, 1933

Type species: *P. primus* Branson & Mehl, 1933

PHRAGMODUS UNDATUS Branson & Mehl

Pl. 1, figures 22, 23, 29.

Phragmodus undatus BRANSON & MEHL, 1933, p. 115-116, pl. 8, figures 22-26; PULSE & SWEET, 1960, p. 257-258, pl. 37, figures 4, 16, 18, 19; text-figure 2, with additional references through March, 1960; CARLSON, 1960, p. 77, pl. 2, figure 14; ETHINGTON & FURNISH, 1960, p. 272, pl. 38, figure 4.

Phragmodus undulatus BRANSON & MEHL, 1944, p. 241, pl. 93, figure 50.

REMARKS.—There is considerable variation among specimens assigned to this species. The three form variants recognized by Sweet *et al* (1959) and Pulse & Sweet (1960) are present in Trenton material.

TYPES.—Figured plesiotypes, NYSM 11853-11855; two unfigured plesiotypes, NYSM 11856-11857.

PHRAGMODUS COGNITUS Stauffer ?

Pl. 1, figure 18.

?*Phragmodus cognitus* STAUFFER, 1935a, p. 150-151, pl. 11, figures 12-14, 18, 31, 41; STAUFFER, 1935b, p. 613, pl. 72, figures 27, 28, 33-37, 39-45, 50.

REMARKS.—A few specimens in Trenton collections exhibit the straight posterior process typical of this species. However, the material is in all cases fragmentary, and so the identification is not certain.

TYPES.—Figured plesiotype, NYSM 11851; unfigured plesiotype, NYSM 11852.

Genus POLYPLACOGNATHUS Stauffer, 1935
Type species: *P. ramosa* Stauffer, 1935

POLYPLACOGNATHUS BILOBATA Schopf, n. sp.
Pl. 1, figures 24, 25, 26, 27, 28.

Ancyrognathus? sp. b STAUFFER, 1935b, p. 602, pl. 75, figures 60, 61.

Amorphognathus sp. MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 30-31.

Polyplacognathus? sp. b STAUFFER, 1935b, p. 616, pl. 75, figures 39, 42, 44, 47; ?pl. 72, figures 8, 11, 12, 16.

?*Amorphognathus* sp. MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figure 32.

DIAGNOSIS.—A species of arched, platform-like conodonts with bifid posterior process, no lateral processes, and an attachment surface typical of *Polyplacognathus*.

DESCRIPTION.—Paired, individually asymmetric, platform-like Y-shaped elements, with postero-laterally inclined cusp situated at junction of long narrow anterior and bifid posterior processes; longer posterior process lobe on side of element toward which cusp inclines. Anterior process denticles, which may be discrete or laterally fused and ridge-like, are separated by transverse grooves and increase in size distally. A row of weakly developed denticles extends from each of two posterior cusp costae down the middle of each posterior process lobe. The entire element is rimmed by low transverse ridges which, in most specimens, are distinct from the main denticle rows.

Underside smooth, lipped marginally, and has a raised median area which contains a narrow basal cavity that extends the full length of the element. Growth lamellae are observable in some specimens, especially on the posterior process.

Dextral specimens have a marked downward flexure just anterior to the cusp (pl. 1, figures 26, 27). This flexure is structurally weak, and most dextral specimens are therefore broken.

REMARKS.—The diagnosis of *Polyplacognathus* given by Sweet & Bergström (1962) applies to this new species, although species heretofore included in that genus have had lateral and unbranched anterior and posterior processes.

TYPES.—Figured holotype, NYSM 11858; figured paratypes, NYSM 11859-11860; 23 unfigured paratypes, NYSM 11861-11862.

POLYPLACOGNATHUS RAMOSA Stauffer

Pl. 1, figures 19, 20, 21.

Polyplacognathus ramosus STAUFFER, 1935b, p. 615, pl. 75, figures 23, 28-31, 37.

Amorphognathus ramosa MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 33-36.

Polyplacognathus ramosa SWEET & BERGSTRÖM, 1962, p. 1235-1237, text-figures 3F, 3G.

Polyplacognathus expensus STAUFFER, 1935b, p. 615, pl. 75, figures 27, 33.

?*Polyplacognathus* sp. a. STAUFFER, 1935b, p. 615-616, pl. 75, figures 32, 36, 38, 43, 48, 49, 62, 63.

?*Polygnathus* sp. STAUFFER, 1932, p. 264, pl. 40, figures 36, 37.

TYPES.—Figured plesiotypes, NYSM 11863-11864; 10 unfigured plesiotypes, NYSM 11865-11866.

Genus PRIONIODINA Bassler, 1925

Type species: *P. subcurvata* Ulrich & Bassler, 1926

PRIONIODINA MACRODENTATA (Graves & Ellison)

Pl. 4, figures 27, 28.

Ozarkodina macrodentata GRAVES & ELLISON, 1941, p. 14, pl. 2, figures 33, 35, 36.

For additional references see SWEET & BERGSTRÖM (1962).

REMARKS.—Specimens referred to *Prioniodina macrodentata* have in common anterior and posterior processes that are bowed toward each other so that, viewed from above, large specimens appear semi-elliptical in outline. The posterior process is longer than the anterior process and, distally, may be twisted 90° out of the plane of the cusp and anterior process so that its basal cavity is directed inward (pl. 4, figure 28). The basal cavity is cone-shaped under the cusp and continues as a groove under the processes.

Prioniodina macrodentata is difficult to distinguish from *P. pulcherrima* when both are represented by small specimens. *P. macrodentata,* however, has a more prominent inner lateral flare of the basal cavity and more compressed processes. In addition, *P. macrodentata* is associated with European conodonts, especially *Ligonodina tortilis* Sweet & Bergström. *P. pulcherrima* is associated with midcontinent conodonts.

TYPES.—Figured plesiotypes, NYSM 11867-11868; 14 unfigured plesiotypes, NYSM 11869-11870.

PRIONIODINA PULCHERRIMA Lindström
Pl. 2, figures 17, 18.

Prioniodina pulcherrima LINDSTRÖM, 1959, p. 442-444, pl. 3, figures 28-30.

Prioniodina delecta SWEET *et al.,* 1959, p. 1060, pl. 131, figure 11; PULSE & SWEET, 1960, p. 258-259, pl. 36, figures 10, 11; BERGSTRÖM, 1964, p. 32-34.

Ozarkodina delecta GLENISTER, 1957, p. 735, pl. 88, figures 8, 9; ETHINGTON, 1959, p. 283-284, pl. 41, figure 17.

Ozarkodina macrodentata ETHINGTON, 1959, p. 284, pl. 41, figure 14.

?*Ozarkodina* ? *delecta* STONE & FURNISH, 1959, p. 225, pl. 32, figures 1, 2.

?*Ozarkodina* sp. MEHL & STROTHMANN, in Branson, 1944, p. 81, pl. 12, figures 14-17.

?*Prioniodina* sp. ETHINGTON & FURNISH, 1960, p. 272, pl. 38, figure 14.

REMARKS.—Specimens referred to *Prioniodina pulcherrima* have in common processes which define vertical planes whose intersection makes an angle of approximately 140°. The prominent compressed cusp is slightly bowed inward. The basal cavity is slightly laterally expanded and extends as a shallow groove under the processes. *P. pulcherrima* is distinguished from *P. oregonia* in that the latter has ovoid cusp and denticles rather than markedly laterally compressed ones. Also, the denticles and cusp of *P. pulcherrima* are basally confluent in most specimens, whereas those of *P. oregonia* remain discrete.

TYPES.—Figured plesiotype, NYSM 11871-11872; nine unfigured plesiotypes, NYSM 11873-11875.

PRIONIODINA ROBUSTA (Stauffer)
Pl. 2, figure 19.

Euprioniodina robusta STAUFFER, 1930, p. 123, pl. 10, figure 1.
Pteroconus tortus BRANSON & MEHL, 1933, p. 112, pl. 8, figure 33.
Ptiloconus tortus SWEET, 1955, p. 246, pl. 28, figure 11.
Pteroconus robustus STAUFFER, 1935b, p. 617, pl. 75, figures 15-17, 20, 21.

REMARKS.—Specimens referred to *Prioniodina robusta* have in common denticulate anterior and posterior processes whose junction makes an angle of about 90° in the vertical plane that contains the processes. The base is laterally expanded on the inner side, and the cusp laterally compressed and inclined inward in most specimens. The anterior process denticles are fewer in number and more widely spaced than those of the posterior process.

TYPES.—Figured plesiotype, NYSM 11876; 11 unfigured plesiotypes, NYSM 11877-11878.

Genus RHIPIDOGNATHUS Branson, Mehl, & Branson, 1951
Type species: *R. symmetrica* Branson, Mehl, & Branson, 1951

RHIPIDOGNATHUS PAUCIDENTATA Branson, Mehl, & Branson
Pl. 2, figure 21.

Rhipidognathus paucidentata BRANSON, MEHL, & BRANSON, 1951, p. 10, pl. 2, figures 18-28; pl. 3, figure 30.

DESCRIPTION.—The anterior and posterior processes and cusp are in nearly the same plane. The anterior process is compressed, slightly bowed inward distally, and has at least six compressed denticles that are basally fused in small specimens and become increasingly fused in larger specimens. The posterior process is compressed and has at least six compressed denticles which are separated in small specimens and medially fused in the largest specimen at hand. Posterior process denticles are smaller and more peg-like than those of the anterior process. The anterior process is directed downward from the horizontal at an angle of about 75°.

The cusp is the largest denticle in all specimens at hand. It is laterally compressed, erect to slightly reclined, and its greatest thickness is just posterior to its mid-width. Inner and outer lateral cusp costae are continuous downward with the crests of the inner and outer postero-lateral flare of the basal cavity. In smaller specimens, the basal cavity lateral flare is pronounced on both sides, but in larger specimens the inner lateral flare is less pronounced. Basal cavity subtriangular in lateral view; its anterior edge is convex, and its posterior edge straight. The apex is beneath the cusp and inclines antero-upward.

REMARKS.—The author is indebted to Drs. Sweet and Bergström who, having found a virtually complete series of growth stages from juvenile to mature specimens of *Rhipidognathus paucidentata* in their study in progress of Cynthiana conodonts, advised him as to the specific determination of specimens at hand. Apparently only a few juvenile specimens are present in the Trenton Group collections. These juveniles may be distinguished from *Prioniodina pulcherrima* and *P. macrodentata* by the greatly different height of the processes in *R. paucidentata.*

TYPES.—Figured plesiotype, NYSM 11879; unfigured plesiotypes, NYSM 11880-11881.

Genus RHYNCHOGNATHODUS Ethington, 1959
Type species: *R. typica* Ethington, 1959

RHYNCHOGNATHODUS DIVARICATUS (Rhodes)
Pl. 3, figure 15.

Trichonodella divaricata RHODES, 1953 (part), p. 313, pl. 21, figures 145, 146 (not pl. 21, figures 124, 140).

Rhynchognathus aborodentata ETHINGTON, 1959, p. 286-287, pl. 41, figures 1, 2.

Rhynchognathodus divaricatus BERGSTRÖM, 1964, p. 36-37, text-figure 18.

Roundya sp. LINDSTRÖM, 1959, p. 448, pl. 3, figures 31-33.

Roundya divaricata LINDSTRÖM, 1959, p. 444, pl. 4, figures 32, 33.

REMARKS.—Trenton and Dubuque representatives of *Rhynchognathodus divaricatus* in Ohio State collections have a basal funnel between processes. This is absent in Rhodes' (1953) Llandeilo material. Bergström (1964) has figured the previously unfigured holotype of *Rhynchognathodus divaricatus.*

There may be some question whether Rhodes' *Trichonodella divaricata* should be assigned to *Rhynchognathodus divaricatus* or *R. typicus.* After viewing the type, the present author agrees with Bergström's assignment of *T. divaricata* to *R. divaricatus,* even if it is admitted that denticles are not as well shown on the anterior lower process as is the case in more typical representatives of that species. If intermediate forms occur, it may introduce the question of whether *R. divaricatus* and *R. typicus* should be kept apart.

TYPES.—Figured plesiotype, NYSM 11882; six unfigured plesiotypes, NYSM 11883.

Rhynchognathodus typicus (Ethington)

Pl. 3, figures 18, 19.

Rhynchognathus typica Ethington, 1959, p. 286, pl. 41, figures 3, 4.

TYPES.—Figured plesiotype, NYSM 11884; 14 unfigured plesiotypes, NYSM 11885.

Genus Rosagnathus Rhodes, 1955

Type species: *R. superbus* Rhodes, 1955

A group of usually associated conodonts representing variations of the same morphologic scheme, previously distributed among species of *Keislognathus, Eoligonodina* (or *Ligonodina), Roundya* (or *Trichonodella),* and *Tetraprioniodus,* is herein considered representative of one genus, *Rosagnathus,* the diagnosis of which is emended to include all these species.

As here emended, *Rosagnathus* includes bilaterally symmetric and asymmetric compound conodonts distinguished by a prominent cusp; a well-developed posterior process, usually with hindeodelloid denticulation; and a downwardly-directed, laterally deflected anterior process that is apically distinct from the cusp. In addition, a lateral process similar in its development to, and subparallel with, the anterior process, may occur on either or both sides of the cusp. The underside of the element is excavated.

Elements in this group with only posterior- and laterally- deflected anterior processes have been included previously in either *Ligonodina* (Rhodes, 1953, 1955; Lindström, 1959) or *Eoligonodina* (Ethington, 1959; Sweet *et al.,* 1959). Asymmetric elements with one lateral process have been referred to *Keislognathus* (Rhodes, 1955; Ethington, 1959; Sweet *et al.,* 1959; Pulse & Sweet, 1960); distinctly symmetric units in this group have been described as species of either *Roundya* or *Trichonodella* (Rhodes, 1955; Lindström, 1959; Ethington, 1959). Elements with four processes have been included in *Tetraprioniodus* or *Rosagnathus* (Rhodes, 1955; Ethington, 1959; Pulse & Sweet, 1960). Thus a variety of generic names is available for the several species in this group. They are here referred to *Rosagnathus* (rather than to *Keislognathus, Ligonodina, Eoligonodina, Roundya,* or *Tetraprioniodus)* because this group contains the oldest type species referable to the generic concept.

Although the number, arrangement, and degree of development of the processes varies somewhat among specimens in *Rosagnathus* as emended, the posterior process of every specimen assigned to *R. delicata* and *R. superbus* is well developed and supports a denticle series arranged in hindeodelloid fashion. This character, and the presence of an anterior process that is distinct from the cusp proximally, serve to distinguish these species from the Lower Ordovician type species of *Tetraprioniodus* and the Upper Ordovician type species of *Eoligonodina,* and they are characters not developed in typical *Trichonodella* or *Roundya. Rosagnathus* is further distinguished from *Trichonodella* by the presence of a well-developed hindeodelloid denticulated posterior process, and from *Roundya* by an attachment surface that is sheathed beneath the entire element.

The type species of *Rosagnathus, Rosagnathus superbus* Rhodes, is Ashgill. Forms included in this species were previously referred to *Rosagnathus superbus* Rhodes (s.s.), *Keislognathus gracilis* Rhodes, *Roundya diminuta* Rhodes, and *Ligonodina* sp. cf. *L. elongata* Rhodes, all of which were described from the Keisley Limestone (Rhodes, 1955).

The oldest species here recognized in *Rosagnathus* is designated *R. valma* (Rhodes). It includes specimens formerly referred to *Ligonodina valma* and *Trichonodella inclinata* by Rhodes, and to *Tetraprioniodus asymmetricus* by Bergström, all of which are known from the Llandeilo Limestone of Wales (Rhodes, 1953; Bergström, 1964).

Specimens referred to *Tetraprioniodus asymmetricus, Ligonodina elongata,* and *Roundya inclinata* by Bergström (1961) from the Ludibundus Limestone of Sweden are intermediate in phylogenetic development between the Llandeilo and middle to upper Caradocian species, i.e., between *Rosagnathus valma* and *R. delicata* defined below. These Ludibundus specimens seem to be more like *R. valma* in their rather closely spaced anterior and lateral process denticles, although it may be admitted that the posterior process is hindeodelloid rather than peg-like in its denticulation, a development which would align these specimens with *R. delicata.* These Ludibundus specimens are here tentatively referred to *R. valma.*

The phylogenetic sequence of these species is the Llandeilo *Rosagnathus valma,* to middle and upper Caradocian *R. delicata,* to the Ashgill *R. superbus. R. delicata* is close to *R. superbus,* but it seems best to keep them distinct, at least until Ashgill forms are better known; at present only one undisputed Welsh Ashgill fauna has been described (Rhodes, 1955).

All or part of the association herein referred to *Rosagnathus* has been reported under various names from the Llandeillo, Crug, and Keisley limestones of Wales (Rhodes, 1953, 1955; Lindström, 1959; Bergström, 1964); from the Ludibundus Limestone of Sweden (Bergström, 1961); from the Eden and Fairview Formations of the Cincinnati region (Sweet *et al.,* 1959; Pulse & Sweet, 1960); from the Dubuque Member of the Galena Formation, and Maquoketa Formation in Iowa (Ethington, 1959; Glenister, 1957); from the Leigh Member of the Bighorn Formation of Wyoming (Stone & Furnish, 1959); and from the Cape (= Fernvale) Limestone of southeastern Missouri (Hardy, 1947, unpublished thesis).

ROSAGNATHUS DELICATA (Branson & Mehl)

Pl. 4, figures 6, 7, 8, 9, 10, 15.

Phragmodus delicatus BRANSON & MEHL, 1933, p. 123, pl. 10, figure 22; GRAVES & ELLISON, 1941, p. 24, pl. 3, figures 12, 13.

Ligonodina elongata RHODES, 1953, p. 305-306, pl. 21, figures 130, 131; LINDSTRÖM, 1959, p. 440, pl. 3, figures 26, 27.

Ligonodina extensa RHODES, 1953, p. 306, pl. 21, figures 128, 129.

Eoligonodina elongata ETHINGTON, 1959, p. 277, pl. 40, figure 5; SWEET *et al.,* 1959, p. 1051, pl. 132, figure 4.

Ligonodina delicata BERGSTRÖM, 1964, p. 28-29, text-figure 12.

Holodontus sp. RHODES, 1953, p. 304.

Trapezognathus? sp. LINDSTRÖM, 1959, p. 448, pl. 3, figures 23-25.

Tetraprioniodus superbus PULSE & SWEET, 1960, p. 260, pl. 36, figure 2.
Keislognathus simplex ETHINGTON, 1059, p. 280-281, pl. 40, figures 9, 10.
Keislognathus gracilis SWEET *et al.,* 1959, p. 1051-1052, pl. 132, figure 11; PULSE & SWEET, 1960, p. 254, pl. 36, figure 3.
Trichonodella inclinata ETHINGTON, 1959, p. 290, pl. 41, figure 6.
Roundya inclinata GLENISTER, 1957, p. 733-734, pl. 88, figure 19.
Hibbardella? gracilis BERGSTRÖM, 1964, p. 24-26.
Trichonodella gracilis RHODES, 1953, p. 314-315, pl. 21, figures 144, 147-150.
Roundya cf. *gracilis* LINDSTRÖM, 1959, p. 446-448, pl. 4, figures 28-31.
cf. *Tetraprioniodus superbus* WOLSKA, 1961, p. 359, pl. 6, figures 1-3.
cf. *Keislognathus gracilis* WOLSKA, 1961, p. 350, pl. 2, figures 2, 3.
cf. *Cordylodus primus* GLENISTER, 1957, p. 732, pl. 88, figure 18.
Keislognathus sp., STONE & FURNISH, 1959, p. 223, pl. 32, figure 6.
Tetraprioniodus superbus STONE & FURNISH, 1959, p. 227, pl. 32, figure 13.

REMARKS.—Diagnostic characters of *Rosagnathus delicata* are the well-developed posterior process hindeodelloid denticulation, the few and widely spaced denticles of the anterior process, and the cusp shape, which is flattened in its lower part and rounded to antero-posteriorly elongate in the upper part.

Two-processed elements are shown in Pl. 4, figures 6, 15; three-processed asymmetric element in Pl. 4, figure 7; three-processed symmetric element in Pl. 4, figures 8, 9; and four-processed element in Pl. 4, figure 10.

TYPES.—Figured plesiotypes, NYSM 11886-11891; 31 unfigured plesiotypes, NYSM 11892.

Genus SAGITTODONTUS Rhodes, 1953
Type species: *S. robustus* RHODES, 1953

SAGITTODONTUS DENTATUS Ethington
Pl. 4, figure 24.

Sagittodontus dentatus ETHINGTON, 1959, p. 287, pl. 39, figure 13; SWEET *et al.,* 1959, p. 1062-1063, pl. 131, figures 7, 8; BERGSTRÖM, 1964, p. 45.

TYPES.—Figured plesiotypes NYSM 11893; 11 unfigured plesiotypes, NYSM 11894-11895.

SAGITTODONTUS ROBUSTUS Rhodes
Pl. 5, figure 31.

Sagittodontus robustus RHODES, 1953, p. 311, pl. 21, figures 141, 142; ETHINGTON, 1959, p. 287-288, pl. 39, figure 12.

Sagittodontus robustus var. *erectus* RHODES, 1953, p. 311, pl. 21, figures 143, 151, 152.

Sagittodontus robustus var. *distaflexus* RHODES, 1953, p. 312, pl. 21, figures 137, 138.

TYPES.—Figured plesiotype, NYSM 11896; 14 unfigured plesiotypes, NYSM 11897.

Genus SCOLOPODUS Pander, 1856
Type species: *S. sublaevis* Pander, 1856

Scolopodus includes multicostate simple cones with or without posterior and anterior keels. Prior to the emendation of Sweet & Bergström (1962), the genus had been confined to symmetrical forms. However, those authors referred to *Scolopodus varicostatus* three "ornament-groups" which were similar in so many ways that they were "compelled to regard the lack of symmetry in two of them as of minor importance in generic assignment."

SCOLOPODUS INSCULPTUS (Branson & Mehl)
Pl. 3, figures 20, 21.

Phragmodus insculptus BRANSON & MEHL, 1933, p. 124, pl. 10, figures 32-34; GRAVES & ELLISON, 1941, p. 24, pl. 3, figure 1; RHODES, 1953, p. 310, pl. 21, figures 136, 153, 154; RHODES, 1955, p. 136-137, pl. 10, figure 17.

Distacodus insculptus ETHINGTON, 1959, p. 275-276, pl. 39, figure 10.

Scolopolus insculptus SWEET *et al.*, 1959, p. 1063, pl. 130, figure 6.

Distacodus insculptus CARLSON, 1960, p. 77, pl. 2, figure 20.

TYPES.—Figured plesiotypes, NYSM 11898-11899; unfigured plesiotype, NYSM 11900.

Genus TRICHONODELLA Branson & Mehl, 1948
Type species: *Trichognathus prima* Branson & Mehl, 1933

TRICHONODELLA BARBARA (Stauffer)
Pl. 2, figures 3, 4, 7, 8, 9.

Trichognathus barbarus STAUFFER, 1935a, p. 155, pl. 12, figure 11.

Trichonodella barbara STONE & FURNISH, 1959, p. 227, pl. 32, figure 15.

Trichognathus minnesotensis STAUFFER, 1935b, p. 619, pl. 71, figures 45, 50.

Trichognathus recurvus STAUFFER, 1935a (part), p. 156, pl. 2, figure 2 (not pl. 12, figure 1); 1935b (part), p. 619-620, pl. 72, figure 56 (not pl. 71, figures 20, 27, 39, 41, 47; pl. 72, figure 48).

DESCRIPTION.—A symmetric *Trichonodella* with denticulate posterior process that forms an angle of about 60° with plane of anterior arch. The lower margin of anterior arch has shape of an inverted U. Lateral processes set with two or more well-developed, discrete denticles. Cusp cross section subrectangular at midheight. Basal cavity a shallow groove under lateral processes, but deeper under posterior process, and expands as conical cavity beneath cusp.

REMARKS.—In *Trichonodella barbara,* the anteriormost lateral process denticles in general are more widely spaced and more rounded than in *T. exacta.* This distinction is not very great, however, and there is a possibility that these are conspecific.

The specimen figured in Pl. 2, figures 3, 4, is tentatively considered a juvenile *T. barbara,* although it may be representative of a distinct species.

TYPES.—Figured plesiotypes, NYSM 11901-11903.

TRICHONODELLA EXACTA Ethington
Pl. 2, figures 1, 2.

Trichonodella exacta ETHINGTON, 1959, p. 290, pl. 41, figures 10, 11.

Trichonodella tenuis SWEET *et al.,* 1959, p. 1065, pl. 132, figures 10, 15; PULSE & SWEET, 1960, p. 261, pl. 37, figures 3, 8.

Trichonodella flexa RHODES, 1953 (part), p. 313-314, pl. 22, figures 181, 182, 191, 192, ?183 (not pl. 22, figures 188, 189).

Trichonodella parabolica LINDSTRÖM (part), p. 450, pl. 1, figures 18, 19 (not pl. 1, figures 20-22).

DESCRIPTION.—A nearly symmetric *Trichonodella,* with denticulate posterior process in juveniles; the denticles are increasingly covered over in more mature forms; distal part of cusp twisted relative to base. Posterior process forms an angle of about 70° with plane of anterior arch. Lower margin of lateral processes nearly straight to slightly convex in most specimens. Upper edge of lateral processes with compressed denticles that are widely spaced in juvenile, and closely spaced in mature specimens; even distally, these denticles in most specimens are directed anteriorly. One denticle occurs on each side anterior to the cusp. Cusp subquadrate proximally, increasingly laterally compressed medially and distally. Basal cavity a shallow groove under lateral processes, a deep groove under posterior process, and a sharp-pointed cavity beneath the cusp.

TYPES.—Figured plesiotypes, NYSM 11904-11905; ten unfigured plesiotypes, NYSM 11906-11907.

TRICHONODELLA FLEXA Rhodes

Pl. 2, figures 5, 6, 10.

Trichonodella flexa RHODES, 1953 (part), p. 313-314, pl. 22, figures 188, 189 (not pl. 22, figures 181-183, 191, 192); GLENISTER, 1957, p. 734, pl. 88, figure 13; ETHINGTON, 1959, p. 290, pl. 41, figures 7, 8.

Trichonodella angulata SWEET *et al.,* 1959, p. 1064, pl. 131, figures 9, 13; PULSE & SWEET, 1960, p. 260-261, pl. 37, figures 2, 7.

Trichognathus delicata BRANSON & MEHL, 1944, p. 241 (as *T.* sp.), pl. 93, figures 62-63.

Trichognathus sp. MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 27, 28.

Trichonodella sp. ETHINGTON & FURNISH, 1959, p. 546, pl. 73, figures 19, 20; 1960 (part), p. 273, pl. 38, figure 6 (not pl. 38, figure 5).

?*Trichonodella parabolica* LINDSTRÖM, 1959 (part), p. 450, pl. 1, figures 20-22 (not pl. 1, figures 18, 19).

?*Trichonodella superba* RHODES, 1953 (part), p. 319, unfigured holotype (not pl. 20, figures 43, 44, 55, pl. 21, figure 132).

DESCRIPTION.—Cusp and undenticulate posterior process deflected laterally, making unit asymmetric; lower margin of lateral processes distinctly concave in outline. Sharply laterally compressed, posterior process departs from plane of anterior arch at an angle of about 60°. Proximal process denticles occur antero-laterally and parallel to cusp, and increase in size to third or fourth from cusp; after this, denticles decrease in size distally and become increasingly directed laterally. Lateral processes compressed and define planes that would intersect between the processes and posterior to the anterior arch at approximately 130° in juvenile, to nearly 180° in mature specimens. Basal cavity is a shallow groove under all three processes, with anteriorly directed conical expansion beneath cusp.

Some few specimens referred to *Trichonodella flexa* are markedly asymmetric because the lateral processes are unevenly developed (Pl. 2, figure 6). The outer lateral process is longer, higher, and has more robust denticles than the inner lateral process. The cusp also differs from typical *T. flexa* in that it is transversely subrectangular in the lower third, rather than elongate antero-posteriorly, with anterior and posterior carinae. These specimens could be recognized as a separate taxon, but until their areal and stratigraphic distribution is better known, it seems best to include them in *T. flexa.*

TYPES.—Figured plesiotypes, NYSM 11908-11910; 19 unfigured plesiotypes, NYSM 11911-11914.

TRICHONODELLA RECURVA (Branson & Mehl)
Pl. 2, figures 14, 15.

Trichognathus recurva BRANSON & MEHL, 1933, p. 119, pl. 10, figure 6; STAUFFER, 1935a (part), p. 156, pl. 12, figure 1 (not pl. 12, figure 2); 1935b (part), p. 619-620, pl. 71, figures 20, 27, 39, 41, 47; pl. 72, figures 48, 56; pl. 75, figure 22 (not pl. 72, figure 56).

DESCRIPTION.—Unsymmetric Trichonodellas with denticulate lateral processes and undenticulate posterior process. At least six, discrete, peg-like denticles present on each lateral process; anteriormost denticle appressed close to cusp, and additional denticles distally increasingly widely spaced and directed laterally. Posterior process curved smoothly upward in cross section. Cusp rounded to subquadrate in cross section. Basal cavity exists as narrow deep groove under lateral processes, as deep excavation under posterior process, and as conical cavity present in the proximal third of cusp.

In a few specimens at hand, a thin basal funnel exists which connects the processes (Pl. 2, figure 14). It is unsymmetrically flexed anteriorly and downward, and posteriorly and upward.

REMARKS.—*Trichonodella recurva* is different from *T. flexa,* also an asymmetric form, in the rounded posterior process of the former and the sharply flexed posterior process of the latter.

TYPES.—Figured plesiotype, NYSM 11915-11916; four unfigured plesiotypes, NYSM 11917.

TRICHONODELLA? TRICURVA Schopf, n. sp.

Pl. 4, figures 19, 20, 21.

Trichognathus cf. *T. erecta* MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 16, 22.

DIAGNOSIS.—Asymmetric pyramidal conodonts, with fused denticles on the two lateral and posterior processes, and a shallow groove extending along the middle of the inverted basal attachment surface.

DESCRIPTION.—Paired, individually asymmetric pyramidal units with a posterior process and asymmetric lateral processes forming an anterior arch. Lateral processes, which are directed downward and distally curved gently backward, bear at least five laterally compressed, medially fused denticles. The outer lateral process is longer, more recurved, and bears more and smaller denticles than the inner lateral process. The proximal denticle on each lateral process is erect and parallel to the cusp; distally, denticles of the inner lateral process remain erect, but those of the outer lateral process can be directed antero-laterally perpendicular to the process.

Posterior process is perpendicular to the cusp axis, but the angle between the outer lateral process and the posterior process is greater than that between the inner lateral process and the posterior process. The posterior process bears at least four laterally compressed, medially fused, upward-directed denticles. Cusp triangular in cross section; low and blunt in most specimens; and its flat to gently convex anterior face is marked at the antero-lateral corners by costae continuous with the lateral processes. Posterior cusp costa continuous with posterior process. Inverted basal attachment surface includes a shallow groove under each process, which is not expanded under cusp.

REMARKS.—*Trichonodella*? *tricurva* is easily distinguished from previously described Ordovician species of *Trichonodella* because of its inverted attachment surface, fused posterior process denticles, and short, stubby cusp. This species is similar to some *Hibbardella* species, but denticles of that genus are discrete rather than fused. The asymmetric, three-limbed nature of *T.*? *tricurva* is similar to *Ambalodus,* but the processes are not sufficiently platform-like to recommend that genus. With increased knowledge of Ordovician three-limbed, cuspate, basally excavated conodonts, it may be advisable to remove *T.*? *tricurva* to a new genus.

TYPES.—Figured holotype, NYSM 11918; 13 unfigured paratypes, NYSM 11919-11922.

Genus ZYGOGNATHUS Branson, Mehl, & Branson, 1951
Type species: *Z. pyramidalis* Branson, Mehl, & Branson, 1951

ZYGOGNATHUS DEFORMIS (Stauffer)
Pl. 4, figures 25, 29, 34.

Trichognathus deformis STAUFFER, 1935a, p. 155-156, pl. 12, figure 3; STAUFFER, 1935b, p. 619, pl. 71, figure 46.

Trichonodella deformis SWEET, 1955, p. 257, pl. 29, figure 6.

Trichognathus illustris STAUFFER, 1935a, p. 156, pl. 12, figure 4.

Gyrognathus elongatus RHODES, 1953, p. 318-319, pl. 22, figures 201, 202, 205, 206.

Gyrognathus superbus RHODES, 1953 (part), p. 319, pl. 20, figures 43, 44, 55, pl. 21, figure 132 (the unfigured holotype = *Trichonodella superba*).

Gyrognathus elongata ETHINGTON, 1959, p. 279, pl. 40, figure 13.

Zygognathus deformis SWEET *et al.*, 1959, p. 1066-1067, pl. 132, figures 1, 5; PULSE & SWEET, 1960, p. 261-262, pl. 37, figures 1, 5.

Zygognathus crugensis LINDSTRÖM, 1959, p. 451, pl. 1, figures 11-15, text-figure 3: 5.

Oulodus (?) sp. MEHL & STROTHMANN, in Branson, 1944, p. 90, pl. 13, figures 14, 15.

?*Phragmodus mirus* BRANSON & MEHL, 1933, p. 123, pl. 10, figure 12.

REMARKS.—In specimens at hand, the posterior cusp flare varies from sharply (Pl. 4, figures 25, 34) to broadly (Pl. 4, figure 29) convex upward in cross section.

TYPES.—Figured plesiotypes, NYSM 11923-11924; 13 unfigured plesiotypes, NYSM 11925.

"FIBROUS" CONODONTS

One hundred and ten "fibrous" conodonts were found in Wilderness strata. About 80 of these were found in lower Wilderness Black River beds and 30 in upper Wilderness beds. Several species are represented by only one specimen, and most specimens are broken. In the absence of large collections, it seemed best to defer specific identification of specimens at hand. Species of seven genera were recognized: *Cardiodella, Curtognathus, Erismodus, Microcoelodus, Ptiloconus,* and *Trucherognathus.*

TYPES.—Figured specimens, NYSM 11930-11932, 11934-11952; four unfigured specimens, NYSM 11953-11956.

CONODONT-LIKE FOSSILS

1. Pl. 4, figures 30, 31, 32, 33. Figure 6d, e.

Specimens such as those figured are superficially like specimens referred to *Pygodus* Lamont and Lindström. That is, they have the same general appearance and properties of conodonts (for example, they sink in tetrabromethane separations for conodonts), and are triangular in upper view, with posterior projections that seem to be the extension of weakly developed denticle rows.

These fossils, however, are the dorsal septum and a small part of the dorsal valve of brachiopods similar in shape to the Cambrian brachiopod *Homotreta interrupta* Bell, (see Bell, 1941, text-figure 2). Dr. Maurits Lindström (pers. comm., 1965) also reports them from Middle Ordovician Swedish deposits.

Apparently the valves of these Middle Ordovician inarticulates were exceedingly fragile, and the septum was the most resistant portion. Diagnostic of this species seems to be the scalloped, posterior margin of the dorsal septum. Some 46 fragments of the brachiopod were found in Barneveld beds. Figure 6 d, e, illustrates the relationship of septum to valve in typical specimens. The author gratefully acknowledges identification of these specimens by Dr. Maurits Lindström.

TYPES.—Figured specimens, NYSM 11744, 11926; unfigured specimens, NYSM 11927-11929.

2. Numerous phosphatic, dog-biscuit shaped fossils, identical to those figured by Stauffer (1935, pl. 12, figures 39, 40, 43, 44) and referred to by him as "plates or skeletal fragments," occur in the Wilderness.

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EXPLANATION OF PLATE 1

Figures are retouched photographs of conodonts from the Trenton and Simcoe Groups, New York and southern Ontario.

Figures 1, 3, 4, 6—*Belodina compressa* (Branson & Mehl). Lateral views of plesiotypes, X36. 1, 3, 62B-K-40; 4, 6, 62B-K-29. NYSM 11729, 11730, 11732, 11731.

2, 9—*Belodina inclinata* (Branson & Mehl). Inner lateral views of plesiotypes, X63. 62B-K-29; 62B-C-13. NYSM 11739, 11740.

5, 8, 12—*Belodina diminutiva* (Branson & Mehl). Inner lateral view of plesiotype, X63. Outer lateral views of plesiotypes, X21, X63. 62B-C-27; 62B-K-18; 62B-C-21. NYSM 11734, 11735, 11736.

7—*Belodina dispansa* (Glenister). Lateral view of plesiotype, X63. 62B-K-40. NYSM 11737.

10, 14—*Oistodus abundans* Branson & Mehl. Lateral views of plesiotypes, X36, X63. 62B-DR-30; 62B-DR-2. NYSM 11809, 11808.

11—*Belodina ornata* (Branson & Mehl). Inner lateral view of plesiotype, X63. 62B-K-[29?]. NYSM 11743.

13—*Oistodus pseudoabundans* Schopf, n. sp. Lateral view of holotype, X63. 62B-K-29. NYSM 11816.

15—*Dichognathus brevis* Branson & Mehl. Antero-lateral view of plesiotype, X63. 62B-DQ-10. NYSM 11761.

16—*Eobelodina fornicala* (Stauffer). Lateral view of plesiotype, X63. 62B-K-40. NYSM 11788.

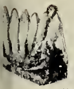
17—*Dichognathus typica* Branson & Mehl. Antero-lateral view of plesiotype, X63. 62B-DQ-10. NYSM 11763.

18—*Phragmodus cognitus* Stauffer? Lateral view of plesiotype, X63. 62B-K-40. NYSM 11851.

19, 20, 21—*Polyplacognathus ramosa* Stauffer. Upper view of sinistral plesiotype, X36. Upper and lower views of dextral plesiotype, X63. 62B-CB-65; 62B-CB-60. NYSM 11864, 11863.

22, 23, 29—*Phragmodus undatus* Branson & Mehl. Lateral views of plesiotypes, X63. 62B-K-45; 62B-K-45; 62B-TR-108. NYSM 11855, 11853, 11854.

24, 25, 26, 27, 28—*Polyplacognathus bilobata* Schopf, n. sp. Upper and lower views of sinistral paratype, X63; 62B-K-29. Lower and upper views of dextral paratype, X63; 62B-KDR-120. Upper view of holotype, X21; 62B-KDR-120. NYSM 11860, 11859, 11858.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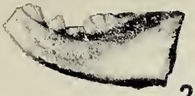
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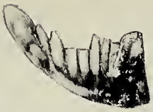
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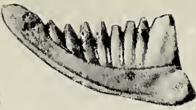
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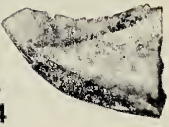
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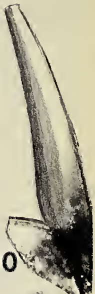
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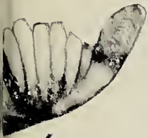
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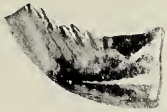
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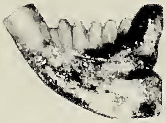
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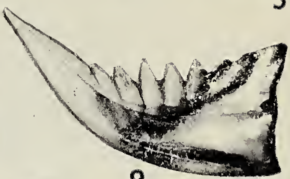
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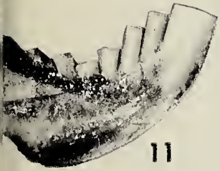
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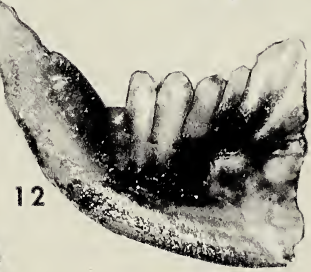
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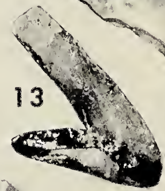
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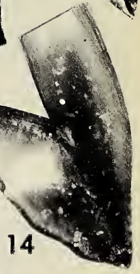
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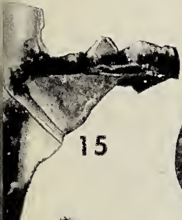
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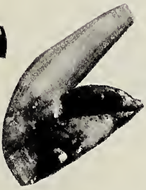
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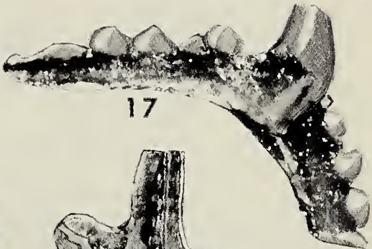
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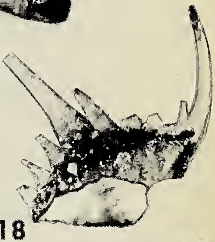
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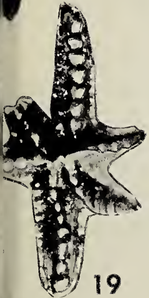
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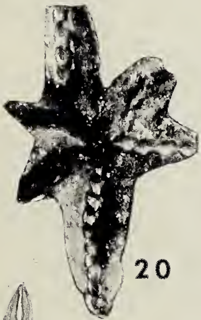
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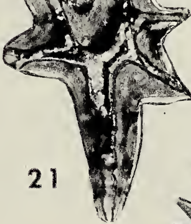
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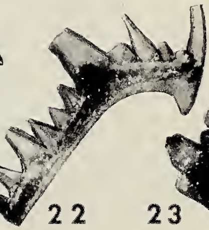
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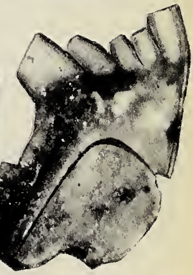
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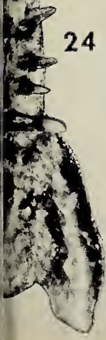
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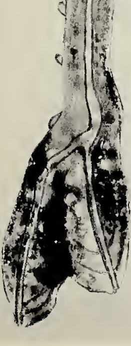
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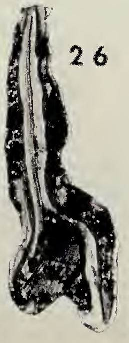
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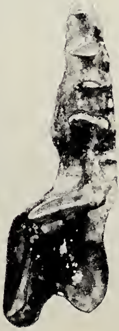
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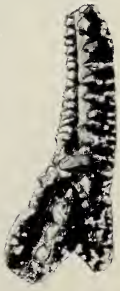
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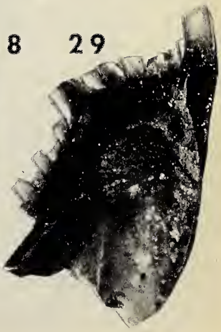
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EXPLANATION OF PLATE 2

Figures are retouched photographs of conodonts from the Trenton and Simcoe Groups, New York, southern Ontario, and Quebec.

Figures 1, 2—*Trichonodella exacta* Ethington. Posterior views of plesiotypes, X36. 62B-DR-86; 62B-DR-168. NYSM 11905, 11904.

3, 4, 7, 8, 9—*Trichonodella barbara* (Stauffer). Posterior, lateral, lateral, posterior, and posterior views of plesiotypes, X63. 62B-K-24; 62B-HCQ-61; 62B-K-2. NYSM 11902, 11903, 11901.

5, 6, 10—*Trichonodella flexa* Rhodes. Postero-lateral, posterior, and postero-lateral views of plesiotypes, X63. 62B-DR-158; 62B-K-24; 62B-DR-119. NYSM 11909, 11908, 11910.

11, 12, 13—*Ozarkodina* cf. *O. tenuis* Branson & Mehl. Lateral views of plesiotypes, X21, X36, X36. 62B-K-2; 62B-K-2; 62B-DR-284. NYSM 11824, 11825, 11823.

14, 15—*Trichonodella recurva* (Branson & Mehl). Posterior views of specimens, X63. 62B-K-2; 62B-HCQ-61. NYSM 11916, 11915.

16—*Cordylodus* n. sp. Inner lateral view of specimen, X63. 62B-K-24. NYSM 11760.

17, 18—*Prioniodina pulcherrima* Lindström. Anterior and posterior views of plesiotypes, X63. 62B-DR-179; 62B-DR-168. NYSM 11872, 11871.

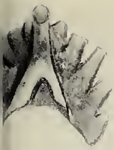
19—*Prioniodina robusta* (Stauffer). Inner lateral view of plesiotype, X63. 62B-K-29. NYSM 11876.

20—*Cordylodus flexuosus* (Branson & Mehl). Inner lateral view of plesiotype, X63. 62B-DR-196. NYSM 11759.

21—*Rhipidognathus paucidentata* Branson, Mehl & Branson. Inner lateral view of plesiotype, X63. 62B-DR-179. NYSM 11879.

22, 23—*Cordylodus delicatus* Branson & Mehl. Outer lateral view and inner lateral view of plesiotypes, X36, X63. 62B-DR-255; 62B-DR-119. NYSM 11753, 11754.

24, 25, 26, 27—*Cordylodus delicatus* Branson & Mehl? Inner lateral views of plesiotypes, X63, X63, X21, X63. 62B-DR-196; 62B-IM-3; 62B-DR-268; 62B-DR-208. NYSM 11758, 11757, 11756, 11755.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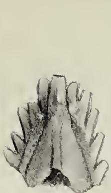
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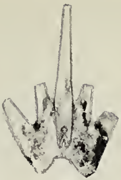
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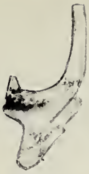
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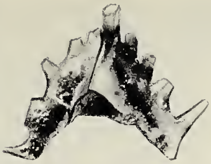
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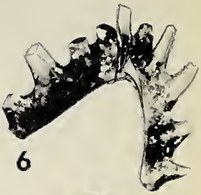
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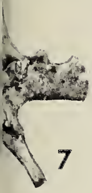
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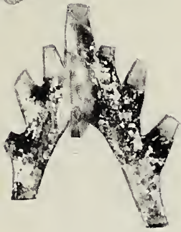
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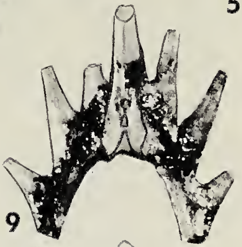
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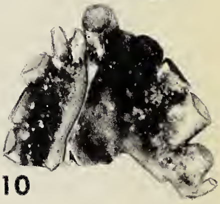
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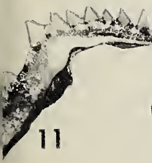
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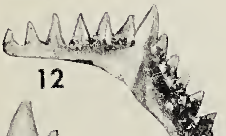
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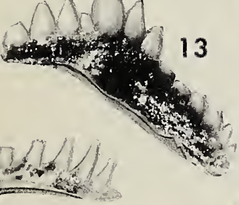
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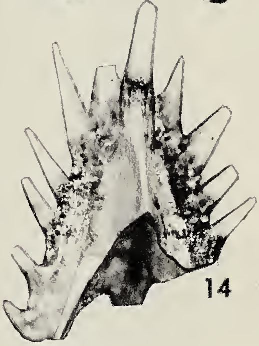
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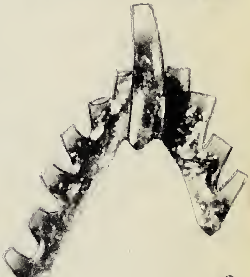
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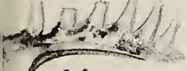
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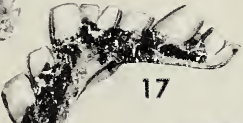
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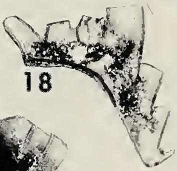
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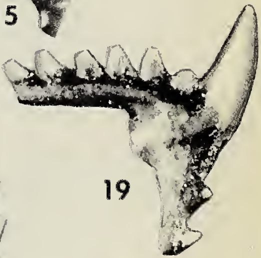
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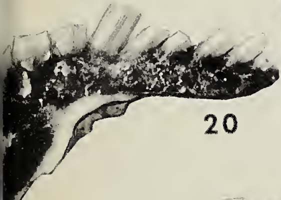
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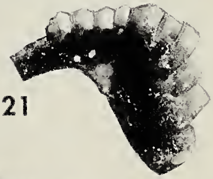
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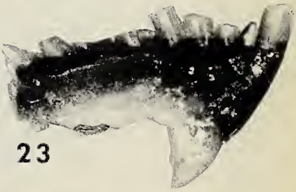
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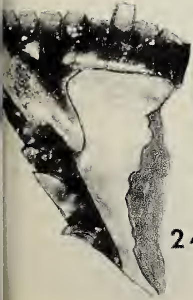
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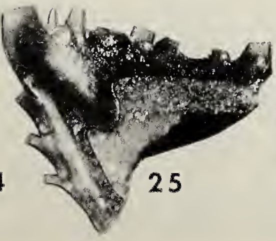
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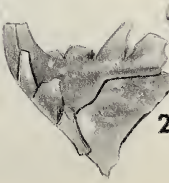
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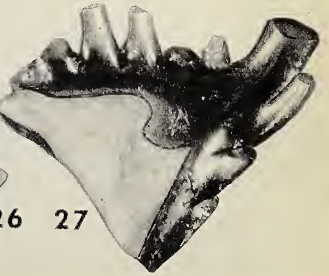
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EXPLANATION OF PLATE 3

Figures are retouched photographs of conodonts from the Trenton Group, New York.

Figures 1, 2, 3, 4, 5, 6, 7—*Amorphognathus ordovicica* Branson & Mehl. Upper surface, blade type; upper and lower surfaces, non-blade and blade type; upper surfaces, blade and non-blade type; plesiotypes, X36. 62B-TR-159; 62B-GS-20; 62B-DR-266; 62B-TR-5; 62B-DR-284. NYSM 11720, 11721, 11722, 11723, 11724.

8, 9—*Amorphognathus tvaerensis* Bergström. Upper surfaces, non-blade type of plesiotypes, X36. 62B-MRB-200; 62B-MRB-170. NYSM 11728, 11727.

10, 12, 13, 14, 16—*Periodon aculeatus* Hadding. Lateral views of plesiotypes, X63. 62B-TR-135; 62B-TR-126; 62B-TR-141; 62B-MAC-10; 62B-TR-141. NYSM 11841, 11843, 11845, 11844, 11842.

11—*Falodus prodentatus* (Graves & Ellison). Lateral view of plesiotype, X63. 62B-TR-168. NYSM 11790.

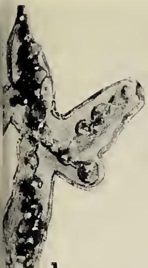
15—*Rynchognathodus divaricatus* (Rhodes). Postero-lateral view of plesiotype, X63. 62B-MRB-140. NYSM 11882.

17, 22, 23—*Icriodella superba* Rhodes. Lateral view posterior process, and lateral view of juvenile plesiotypes; lateral view, anterior process of mature plesiotype, X63. 62B-DQ-10; 62B-TR-98; 62B-MRB-140. NYSM 11801, 11799, 11800.

18, 19—*Rhynchognathodus typicus* Ethington. Inner and outer lateral views of plesiotype, X63. 62B-DR-168. NYSM 11884.

20, 21—*Scolopodus insculptus* (Branson & Mehl). Lateral views of juvenile and mature plesiotypes, X63. 62B-TR-112; 62B-GS-1. NYSM 11898, 11899.

24, 25—*Paltodus dissimilaris* (Branson & Mehl). Inner and outer lateral views of plesiotype, X36. 62B-TR-177. NYSM 11831.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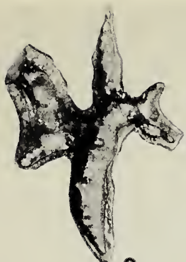
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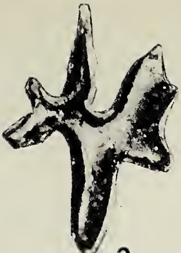
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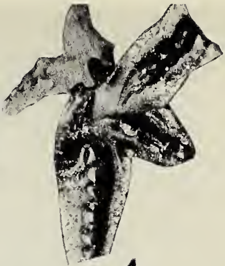
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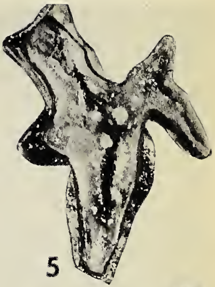
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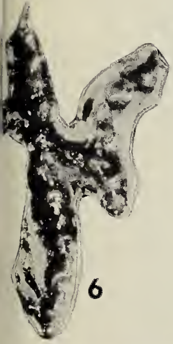
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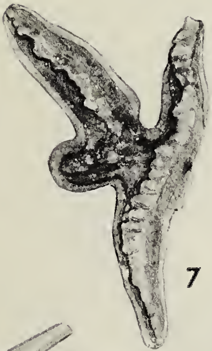
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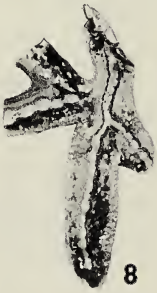
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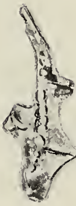
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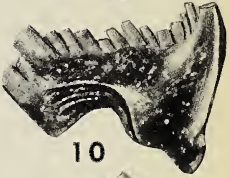
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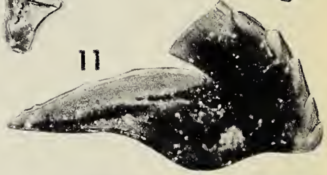
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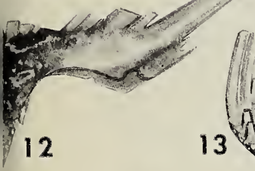
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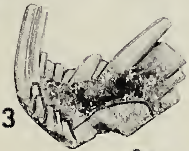
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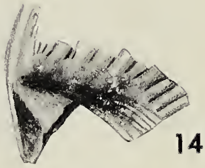
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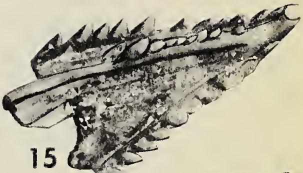
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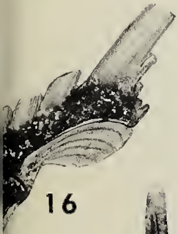
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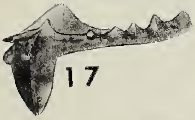
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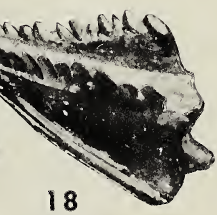
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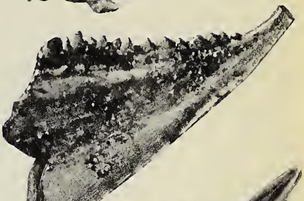
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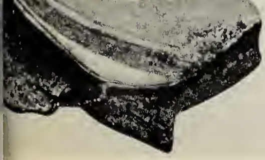
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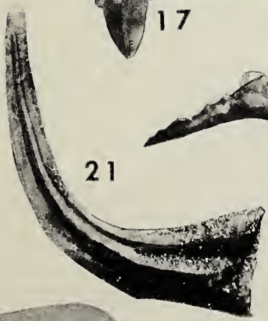
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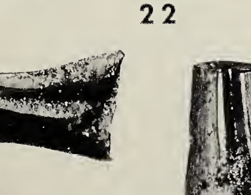
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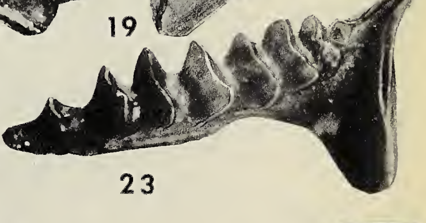
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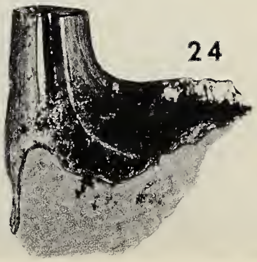
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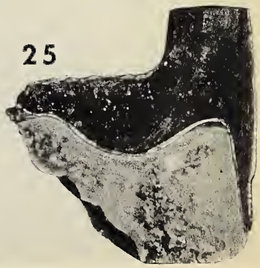
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EXPLANATION OF PLATE 4

Figures are retouched photographs of conodonts from the Trenton and Simcoe Groups, New York and southern Ontario.

Figures 1, 2, 3, 4, 5—*Ambalodus triangularis* Branson & Mehl. Antero-upper, posterior, outer lateral, antero-upper, and anterior views of plesiotypes, X36. 62B-CB-105; 62B-TR-57; 62B-TR-4. NYSM 11715, 11716, 11717.

6, 7, 8, 9, 10, 15—*Rosagnathus delicata* (Branson & Mehl). Lateral views of plesiotypes, X63. 62B-TR-108; 62B-DR-268; 62B-MRB-130; 62B-CB-75; 62B-TR-88.5; 62B-TR-48. NYSM 11886, 11890, 11889, 11888, 11891, 11887.

11—*Ambalodus elegans* (Rhodes). Outer lateral view of plesiotype, X63. 62B-MRB-140. NYSM 11711.

12—*Ambalodus pulcher* (Rhodes). Outer lateral view of plesiotype, X63. 62B-MRB-140. NYSM 11713.

13, 14—*Bryantodina abrupta* (Branson & Mehl). Lateral views of plesiotypes, X36. 62B-K-29; 62B-K-24. NYSM 11745, 11746.

16, 17—*Holodontus superbus* Rhodes. Posterior views of plesiotypes, X63. 62B-MRB-160; 62B-CB-105. NYSM 11795, 11794.

18—*Goniodontus superbus* Ethington. Posterior view of plesiotype, X63. 62B-GS-35. NYSM 11792.

19, 20, 21—*Trichonodella? tricurva* Schopf, n. sp. Lateral, posterior, and anterior views of holotype, X63. 62B-K-29. NYSM 11918.

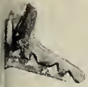
22, 23, 26—*Ligonodina tortilis* Sweet & Bergström. Lateral views, posterior and anterior processes, and posterior process of plesiotypes, X63. 62B-TR-141; 62B-TR-177. NYSM 11805, 11804.

24—*Sagittodontus dentatus* Ethington. Lateral view of plesiotype, X63. 62B-MRB-150. NYSM 11893.

25, 29, 34—*Zygognathus deformis* (Stauffer). 25, 34, posterior and postero-lateral views of plesiotypes, X36, X63. 29, posterior view of plesiotype, X63. 62B-DR-240; 62B-DR-187. NYSM 11923, 11924.

27, 28—*Prioniodina macrodentata* (Graves & Ellison). Inner lateral views of plesiotypes, X63. 62B-TR-135; 62B-TR-126. NYSM 11867, 11868.

30, 31, 32, 33—Dorsal septum of Brachiopod. Upper surface [two exposures] and lower surface of specimen, X63. Upper surface of specimen, X63. 62B-CB-105; 62B-CB-105. NYSM 11744, 11926.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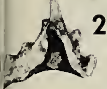
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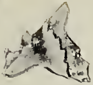
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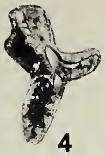
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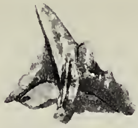
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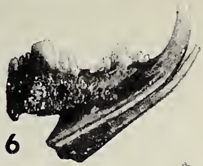
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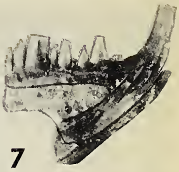
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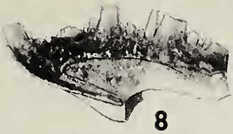
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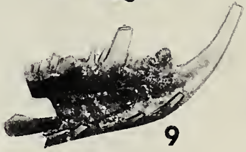
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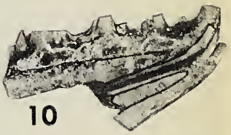
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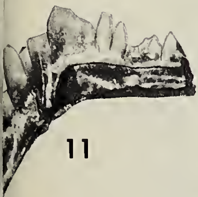
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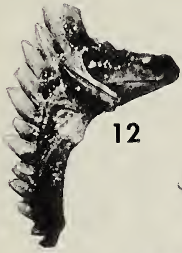
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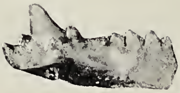
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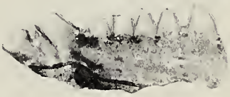
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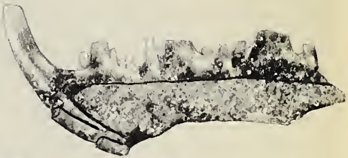
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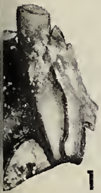
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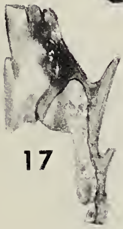
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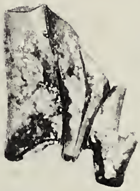
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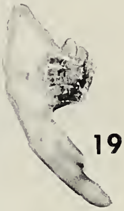
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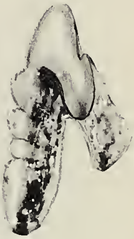
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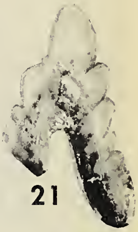
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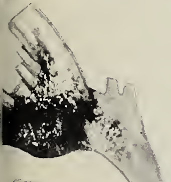
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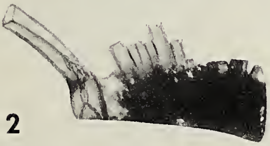
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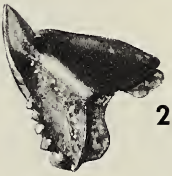
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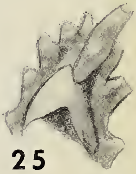
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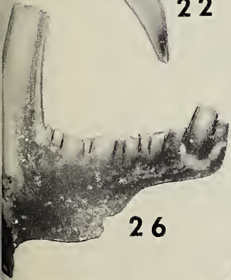
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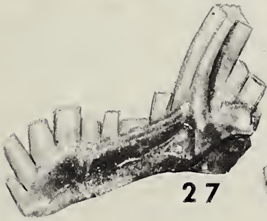
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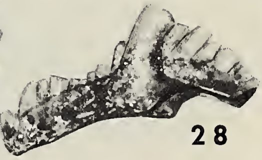
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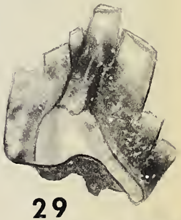
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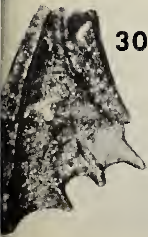
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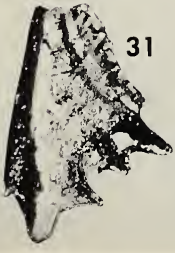
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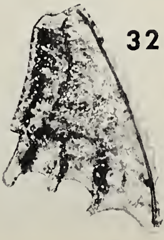
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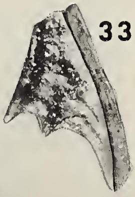
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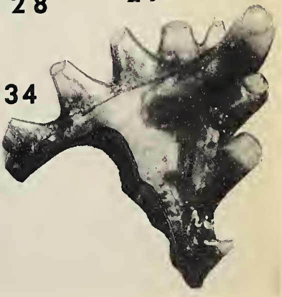
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EXPLANATION OF PLATE 5

Figures are retouched photographs of conodonts from the Trenton and Simcoe Groups, New York and southern Ontario.

Figures 1—*Distacodus procerus* Ethington. Lateral view of plesiotype, X63. 62B-TR-186. NYSM 11769.

2, 3, 4—*Distacodus*? *trigonius* Schopf, n. sp. Inner lateral, posterior, and outer lateral views of holotype, X63. 62B-DR-270. NYSM 11772.

5, 6, 7—*Acontiodus*? *curvus* Schopf, n. sp. Lateral views of holotype and paratypes, X63. 62B-TR-195; 62B-MRB-130; 62B-TR-141; NYSM 11706, 11707, 11708.

8—*Coelocerodontus tetragonius* Ethington. Lateral view of plesiotype, X63. 62B-MAC-40. NYSM 11749.

9—*Coelocerodontus trigonius* Ethington. Lateral view of plesiotype, X63. 62B-DR-179. NYSM 11751.

10—*Oistodus inclinatus* Branson & Mehl. Lateral view of plesiotype, X36. 62B-DR-2. NYSM 11813.

11, 14, 15—*Drepanodus* cf. *D. homocurvatus* Lindström. Lateral views of plesiotypes, X36. 62B-DR-10; 62B-KDR-148; 62B-KDR-148. NYSM 11785, 11783, 11784.

12—*Drepanodus amoenus* Lindström. Lateral view of plesiotype, X36. 62B-DR-130. NYSM 11776.

13—*Drepanodus* cf. *D. arcuatus* of Lindström [1955a]. Lateral view of plesiotype, X36. 62B-KDR-22. NYSM 11781.

16—*Acontiodus falcatus* Ethington?. Posterior view of plesiotype, X36. 62B-DR-216. NYSM 11704.

17—*Acodus numaltipes* Schopf, n. sp. Lateral view of holotype, X63. 62B-TR-141. NYSM 11695.

18—*Acodus* aff. *A. unicostatus* Branson & Branson. Inner lateral view of plesiotype, X63. 62B-DR-228. NYSM 11700.

19—*Oistodus venustus* Stauffer. Lateral view of plesiotype, X63. 62B-MRB-140. NYSM 11820.

20—*Acodus inornatus* Ethington. Outer lateral view of plesiotype, X63. 62B-K-29. NYSM 11691.

21—*Drepanodus planus* Lindström. Lateral view of plesiotype, X63. 62B-MRB-170. NYSM 11777.

22, 24—*Panderodus striatus* (Stauffer). Posterior and lateral views of plesiotype, X63. 62B-KDR-10. NYSM 11838.

23—*Panderodus compressus* (Branson & Mehl). Lateral view of plesiotype, X63. 62B-K-40. NYSM 11834.

25—*Drepanodus suberectus* (Branson & Mehl). Lateral view of plesiotype, X63. 62B-DQ-10. NYSM 11779.

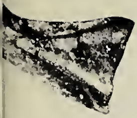
26, 28—*Panderodus arcuatus* (Stauffer). Posterior and inner lateral views of plesiotype, X63. 62B-K-40. NYSM 11832.

27—*Distacodus falcatus* Stauffer. Lateral view of plesiotype, X63. 62B-TR-225. NYSM 11765.

29—*Acodus similaris* Rhodes. Lateral view of plesiotype, X63. 62B-CB-105. NYSM 11698.

30—*Panderodus feulneri* (Glenister). Lateral view of plesiotype, X63. 62B-MAC-10. NYSM 11837.

31—*Sagittodontus robustus* Rhodes. Lateral view of plesiotype, X36. 62B-MRB-130. NYSM 11896.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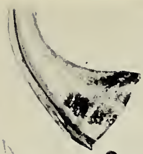
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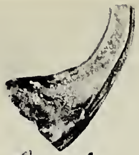
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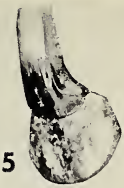
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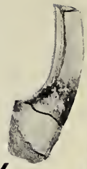
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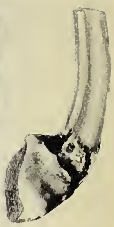
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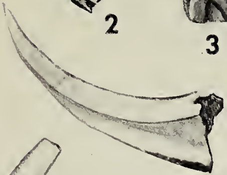
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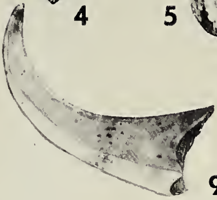
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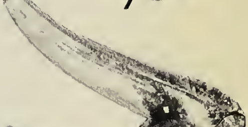
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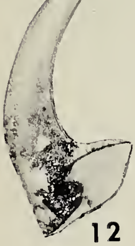
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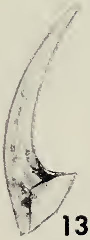
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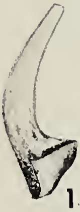
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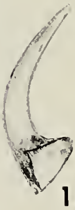
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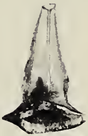
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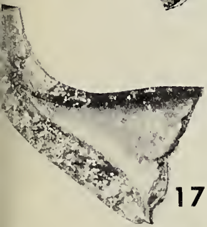
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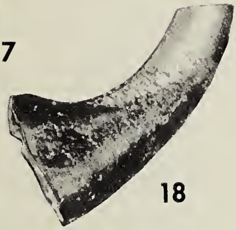
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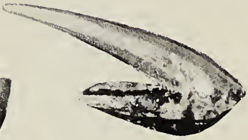
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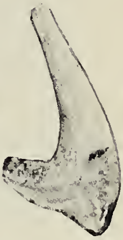
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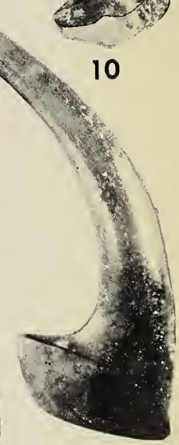
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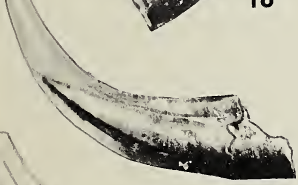
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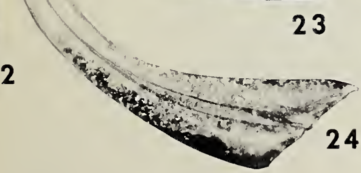
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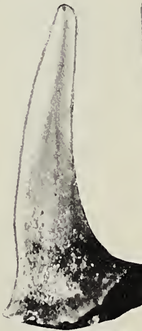
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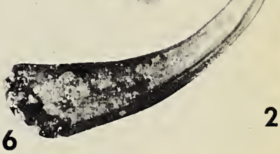
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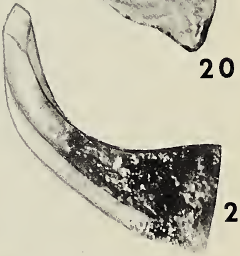
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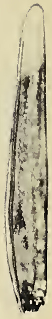
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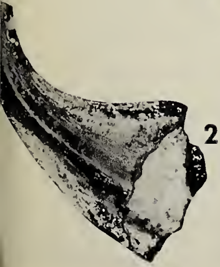
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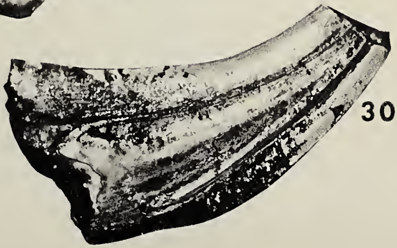
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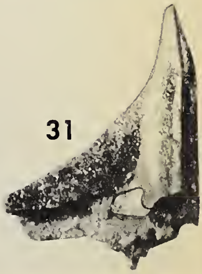
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EXPLANATION OF PLATE 6

Figures are retouched photographs of conodonts from the Black River, Trenton and Simcoe Groups, New York and southern Ontario.

Figures 1—*Ptiloconus*? sp. Posterior view of specimen, X36. 62B-LO-71. NYSM 11930.

2—*Curtognathus*? sp. Lateral view of specimen, X63. 62B-LO-71. NYSM 11931.

3—*Curtognathus* sp. Posterior view of specimen, X36. 62B-LO-31.5. NYSM 11932.

4—*Ptiloconus* sp. Postero-lateral view of specimen, X36. 62B-LO-47.5. NYSM 11934.

5—*Polycaulodus* sp. Lateral view of specimen, X36. 62B-C-13. NYSM 11935.

6—*Polycaulodus* sp. Lateral view of specimen, X36. 62B-CB-1. NYSM 11936.

7—*Curtognathus*? sp. Posterior view of specimen, X36. 62B-LO-71. NYSM 11937.

8—*Curtognathus*? sp. Lateral view of specimen, X63. 62B-LO-1. NYSM 11938.

9—*Cordylodus* sp. Lateral view of specimen, X63. 62B-LO-31.5. NYSM 11939.

10—*Erismodus*? sp. Lateral view of specimen, X36. 62B-LO-1. NYSM 11940.

11—*Trucherognathus*? sp. Anterior view of specimen, X36. 62B-C-13. NYSM 11941.

12—*Microcoelodus* sp. Lateral view of specimen, X63. 62B-LO-31.5. NYSM 11942.

13—*Erismodus* sp. Posterior view of specimen, X63. 62B-LO-31.5. NYSM 11943.

14—*Cardiodella* sp. Anterior view of specimen, X36. 62B-IM-1. NYSM 11944

15—*Cardiodella*? sp. Postero-lateral view of specimen, X36. 62B-IM-20. NYSM 11945.

16—*Trucheragnathus* sp. Lateral view of specimen, X36. 62B-LO-31.5. NYSM 11946.

17—*Curtognathus*? sp. Lateral view of specimen, X36. 62B-DQ-70. NYSM 11947.

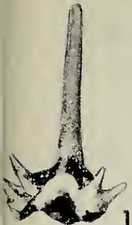
18—*Cardiodella* sp. Anterior view of specimen, X36. 62B-IM-31.5. NYSM 11948.

19—*Curtognathus*? sp. Lateral view of specimen, X36. 62B-C-21. NYSM 11949.

20—*Erismodus* sp. Posterior view of specimen, X36. 62B-LO-47.5. NYSM 11950.

21—*Belodina* sp. Lateral view of specimen, X21. 62B-LO-31.5. NYSM 11951.

22—*Curtognathus*? sp. Lateral view of specimen, X36. 62B-LO-44.5. NYSM 11952.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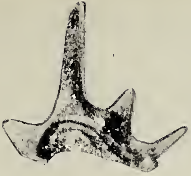
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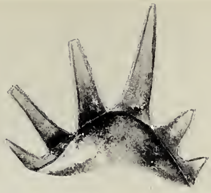
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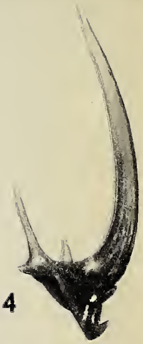
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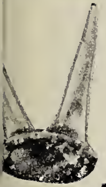
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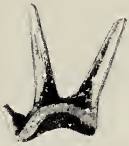
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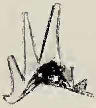
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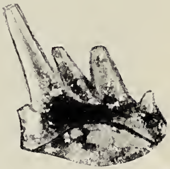
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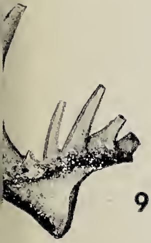
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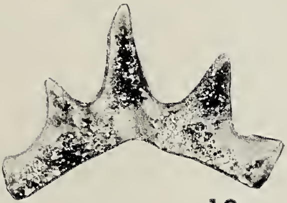
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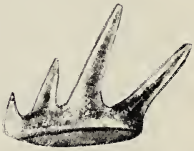
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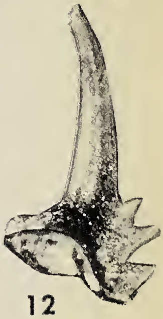
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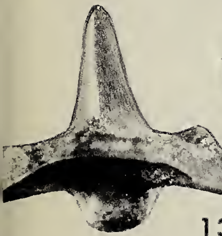
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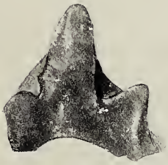
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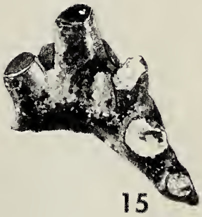
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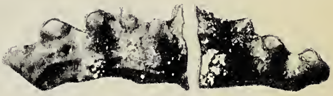
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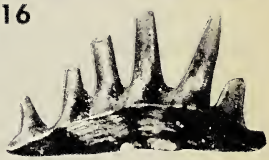
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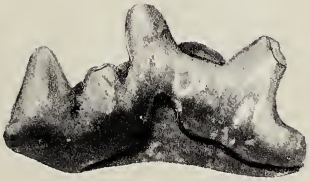
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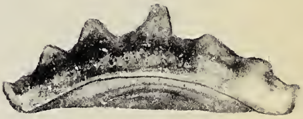
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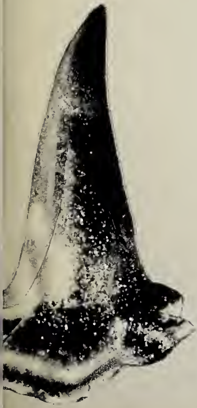
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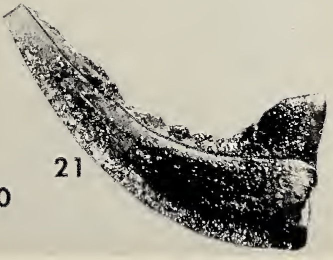
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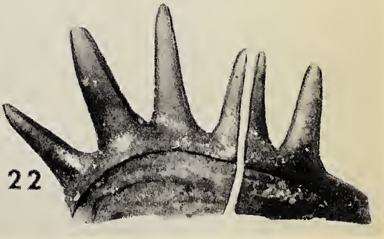
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Mammals of the Tug Hill Plateau, New York

by

Paul F. Connor

Scientist
New York State Museum and Science Service

BULLETIN NUMBER 406

NEW YORK STATE MUSEUM AND SCIENCE SERVICE

*The University
of the State
of New York*

ALBANY, NEW YORK

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155

Contents

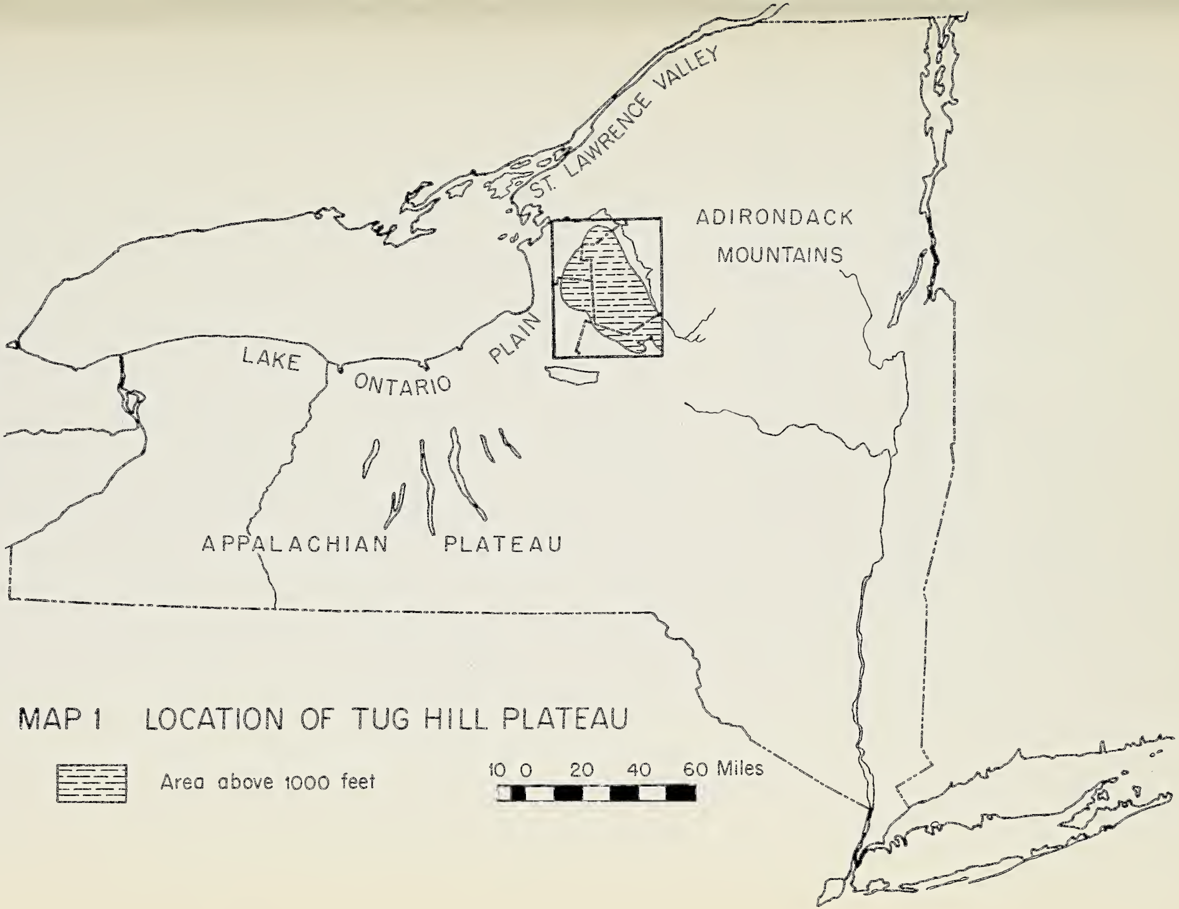
PAGE

1 **INTRODUCTION**
5 **ACKNOWLEDGMENTS**
7 **DESCRIPTION OF REGION**
16 **ACCOUNTS OF MAMMALS**
16 Opposum
17 Masked Shrew
18 Smoky Shrew
20 Water Shrew
30 Pygmy Shrew
30 Short-Tailed Shrew
31 Hairy-Tailed Mole
33 Star-Nosed Mole
34 Little Brown Bat
35 Silver-Haired Bat
35 Big Brown Bat
36 Red Bat
36 Hoary Bat
37 Varying Hare
38 Eastern Cottontail
38 Woodchuck
39 Eastern Chipmunk
41 Gray Squirrel
41 Red Squirrel
43 Southern Flying Squirrel
43 Northern Flying Squirrel
44 Beaver
45 Deer Mouse
46 Prairie Deer Mouse
47 White-footed Mouse

SMITHSONIAN INSTITUTION JUN 22 1966

PAGE

47 Red-Backed Mouse
49 Meadow Mouse or Meadow Vole
51 Pine Mouse or Pine Vole
53 Muskrat
53 Norway Rat
53 House Mouse
54 Meadow Jumping Mouse
55 Woodland Jumping Mouse
57 Porcupine
58 Coyote
59 Red Fox
59 Gray Fox
60 Black Bear
61 Raccoon
61 Fisher
62 Short-Tailed Weasel or Ermine
64 Long-Tailed Weasel
65 Mink
65 Striped Skunk
66 River Otter
66 Bobcat
67 White-Tailed Deer
68 **PHOTOGRAPHS OF HABITATS**
75 **THE SIPHONAPTERA—by Allen H. Benton**
78 **REFERENCES CITED**



MAP 1 LOCATION OF TUG HILL PLATEAU

The Mammals of the Tug Hill Plateau, New York[1]

by Paul F. Connor

INTRODUCTION

THE TUG HILL PLATEAU, or simply Tug Hill,* as it is generally called, is situated in northern New York between the eastern end of Lake Ontario and the Adirondack Mountains (Map 1). This highland area, which is largely wooded, differs from the Adirondack Mountains in many respects (see Description of Region) and is separated from them by the low, cultivated valley of the Black River. A section of approximately 100,000 acres in the central elevated region of Tug Hill in Lewis County is densely forested except for swamps and meadows in places along the streams, and may be considered a wilderness area; it is not permanently inhabited and is essentially roadless, although secondary roads form a network on the edge of the plateau around this central region. A few unimproved dead-end roads and truck trails penetrate further into the woods, and only one of these, heading west from Houseville and useable for only a few months of the year at the time this study was made, penetrates into the center of the wild upper area. One is constantly warned by the local inhabitants of the region against becoming lost on Tug Hill, perhaps with good reason, because of the unvarying flat sameness of the dense woods and bushy swamps.

This wilderness section and the plateau in general have been neglected by field zoologists, although probably receiving slightly more attention in the last decade or so than formerly. Besides its somewhat isolated and inaccessible location, Tug Hill apparently has been overlooked, or has been thought of as merely an extension of the larger and more scenic Adirondack area to the east. The following are some pertinent references on Tug Hill and vicinity which have come to my attention. The most useful general and botanical description of Tug Hill, and which includes a list of the vascular plants, is the publication by Hotchkiss (1932). Publications covering this area briefly from the forestry viewpoint include Armstrong (1954) and Stout (1958). Three of the State biological surveys of stream systems in relation to fisheries (Moore, Greeley, et al. 1928, 1932, 1940) touch on parts of the Tug Hill area. Eldridge (1952) made an economic study of the wildlife of Lewis County in general. Brief, but interesting published notes on breeding birds of the area include Arbib (1953) and Scheider (1959, 1960). So far as I know, nothing has been published on the status of the amphibians, reptiles, or mammals of Tug Hill. In the nineteenth century, C. Hart Merriam collected mammals near his home at Locust Grove, a small village about six miles north of Boonville, on the fringe area of Tug Hill, west of the Black River, but below the eastern escarpment of the plateau, at an altitude of about 1340 feet. In his study of the mammals of the Adirondacks, Merriam (1882-84) mentions several species collected here, referring to this locality as "on the outskirts of the Adirondacks", but evidently he did not collect farther west on the plateau proper. Some of his records of special interest are included in the present report. Townsend (1935) conducted small mammal studies in several lowland localities southwest of Tug Hill near Oneida Lake, while Gordon (1951) gathered information on the occurrence of mammals in Jefferson County to the north of Tug Hill.

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[1] Manuscript submitted for publication July 21, 1965.

* Another Tug Hill, much smaller in extent, is located five miles southwest of Cattaraugus.

This field study was done between August 1960, and August 1961, as part of a continuing survey of small mammals in New York State. An earlier phase conducted in Otsego and Schoharie counties while participating in a State investigation of rabies in wildlife, has been published (Connor, 1960). The work on Tug Hill was devoted mainly to the collecting of mammals ranging in size from shrews to weasels and squirrels. Approximately 1,425 mammals of 22 species were collected, using principally mouse traps, rat traps, and small sunken cans. All preserved mammal skins, skulls, and skeletons are located at the New York State Museum in Albany, as are individual data sheets for most of the specimens collected. Much of the information obtained on the distribution, ecology, habits, etc., of small mammals taken on Tug Hill is covered in this report. Also, notes are included on other mammals of the region, based on our own field observations, the limited literature, and certain unpublished records (especially of the Conservation Department) made available to me. Ectoparasites were saved, and information on the Siphonaptera (fleas) collected in 1960 is presented separately in this publication.

The water shrew has been treated at greater length than the other small mammals. Little has been published on the life history of this interesting shrew in the northeastern United States, and its presence on Tug Hill encouraged extra concentration of effort on this species. All stomach determinations, except of fungus spores, were made by the author. The contents of individual stomachs were placed in water in watch-glasses, teased apart, rinsed as necessary, and examined under a binocular dissecting microscope; the percentages of the various items were roughly estimated. The volumetric percentages given for the various foods are meant to indicate only approximately the actual food habits of the animals.

Trapping was done on the plateau during all months of the year except March. Most of the habitats on the flat upper level were included. Coverage was fairly good in the more broken country along the eastern rim of the plateau. Less time was spent on the lower slopes and adjoining lowlands. During the winter, because of the deep snow, trapping was confined primarily to certain places on the upper level near plowed roads and a few lower slope and valley localities. Details on elevations and habitats are given in *Description of Region.*

Localities trapped, all of which are located in Lewis County, may be grouped as follows: 1. Many locations along the narrow woods road which crosses the center of the Tug Hill woods in the towns of Highmarket and Osceola, passable with care in 1959-60, to 12 miles or more west of Houseville; an old logging route, formerly laid with railroad track (Glenfield and Western Railroad), that goes through the now uninhabited sites of Tabolt Corners, Page, and Old Campbellwood; 2. localities west and south of Lowville on the northeastern slope and along the northern fringe of the central forested section, in the towns of Martinsburg and Montague, including the vicinities of Whetstone Gulf, Roaring Brook, Haber Pond, Sears Pond, and Rector; 3. somewhat lower elevations on the forested south slope of Tug Hill, in the towns of Lewis and Osceola, between the villages of West Leyden and North Osceola; and 4. the lower slopes, and the valley of the Black River 2 to 5 miles southeast of Lowville in the town of Martinsburg. Most of the time was devoted to the first two, higher sections (1 and 2).

General observations of habitats and wildlife were made elsewhere on the plateau.

The mammal accounts are concerned mainly with those forms occurring on the top and upper slopes of Tug Hill, where the work was concentrated. At least 38 species are in this group. The following 36 were recorded in our field survey on the upper part of the plateau above 1700 feet: masked shrew, smoky shrew, water shrew, short-tailed shrew, hairy-tailed mole, star-nosed mole, little brown bat, big brown bat, silver-haired bat (?), varying hare, woodchuck, eastern chipmunk, red squirrel, northern flying squirrel, beaver, deer mouse, white-footed mouse, red-backed mouse, meadow mouse, pine mouse, muskrat, Norway rat, house mouse, meadow jumping mouse, woodland jumping mouse, porcupine, coyote, red fox, raccoon, long-tailed weasel, short-tailed weasel, mink, striped skunk, otter, bobcat, and white-tailed deer. A few other species also are known to occur on the upper part of the hill, such as the fisher. Also included in the accounts are several species from areas immediately adjacent—the valley of the Black River and low elevations on the fringe of the plateau, although some of these species may be found occasionally or in smaller numbers on top of the plateau. The mammals listed, and discussed in the accounts, are the forms which, as far as my present information goes, now occur on Tug Hill or at lower altitudes closely bordering the hill.

The following forms, not discussed in the accounts, are mentioned briefly in passing. Now extirpated on Tug Hill, but undoubtedly part of the original fauna as it existed into recent times, and probably well into the last century, are the gray wolf *(Canis lupus)*, marten *(Martes americana)*, mountain lion *(Felis concolor)*, Canada lynx *(Lynx canadensis)*, and moose *(Alces alces)*; the wapiti *(Cervus canadensis)* and probably the wolverine *(Gulo luscus)* also lived in the region within historical times, but disappeared earlier. The lynx has continued to exist very sparingly in northern New York and may possibly appear again on Tug Hill. For the marten, I received several unverified winter track reports from Tug Hill; subsequent to 1946, the marten has increased in the Adirondacks (Hamilton, 1958), so possibly there is a chance of its becoming reestablished on outlying Tug Hill.

Certain small, elusive mammals, so far undetected anywhere on Tug Hill, may occur locally in small numbers. The big-tailed shrew *(Sorex dispar)* and the rock vole *(Microtus chrotorrhinus)* exist in the eastern Adirondacks and in the Catskills; on Tug Hill, though, there is little if any rocky habitat which appears suitable to the requirements of these species, and although the possibility of a few widely scattered colonies cannot be ruled out, it seems unlikely that either of these animals live in the region. The southern bog lemming *(Synaptomys cooperi)* is more likely to occur. I expected to locate this species in the moist woods and bogs on top of the plateau, but no evidence of its presence could be found; perhaps it occurs locally on the lower slopes in woods that are drier, but which contain patches of certain sedges *(Carex)*, somewhat resembling situations in east-central New York where *Synaptomys* is fairly common. More remains to be learned regarding the status of bats on the plateau. Bat hunting gave poor returns: open ponds for observing and collecting are scarce, and at some of these no bats were seen, yet by trying a variety of collecting techniques in different situations, it seems likely that additional species could be recorded. In addition to the bats briefly discussed in the accounts, Tug Hill is within the range of Keen's bat (*Myotis keenii*), least brown bat *(Myotis subulatus)* and eastern pipistrelle *(Pipistrellus subflavus);* Keen's bats, not rare in New York, probably went undetected in flight among the more numerous little brown bats *(Myotis lucifugus).*

ACKNOWLEDGMENTS

The small mammal survey is being carried out under the direction of Ralph S. Palmer, State Zoologist. During the summer (1960), James E. Brower assisted by trapping and preparing study specimens of small mammals. I wish to thank all of the following who helped in special ways. John E. Wilson, Regional Supervisor for Fish and Game of the New York State Conservation Department, read that part of the manuscript dealing with the larger mammals and contributed locality records for several of these species. He also suggested other sources of information. Allen H. Benton of the State University College at Fredonia, identified the Siphonaptera collected, and wrote the annotated list of these parasites. Alexander Bakerspigel of the University of Western Ontario and Rodney C. De Groot of the New York State Museum and Science Service identified samples of fungi, especially *Endogone,* encountered in stomach analyses. Catch records of State fox trappers engaged in rabies control in the region were provided by Eugene Parker and Franz C.

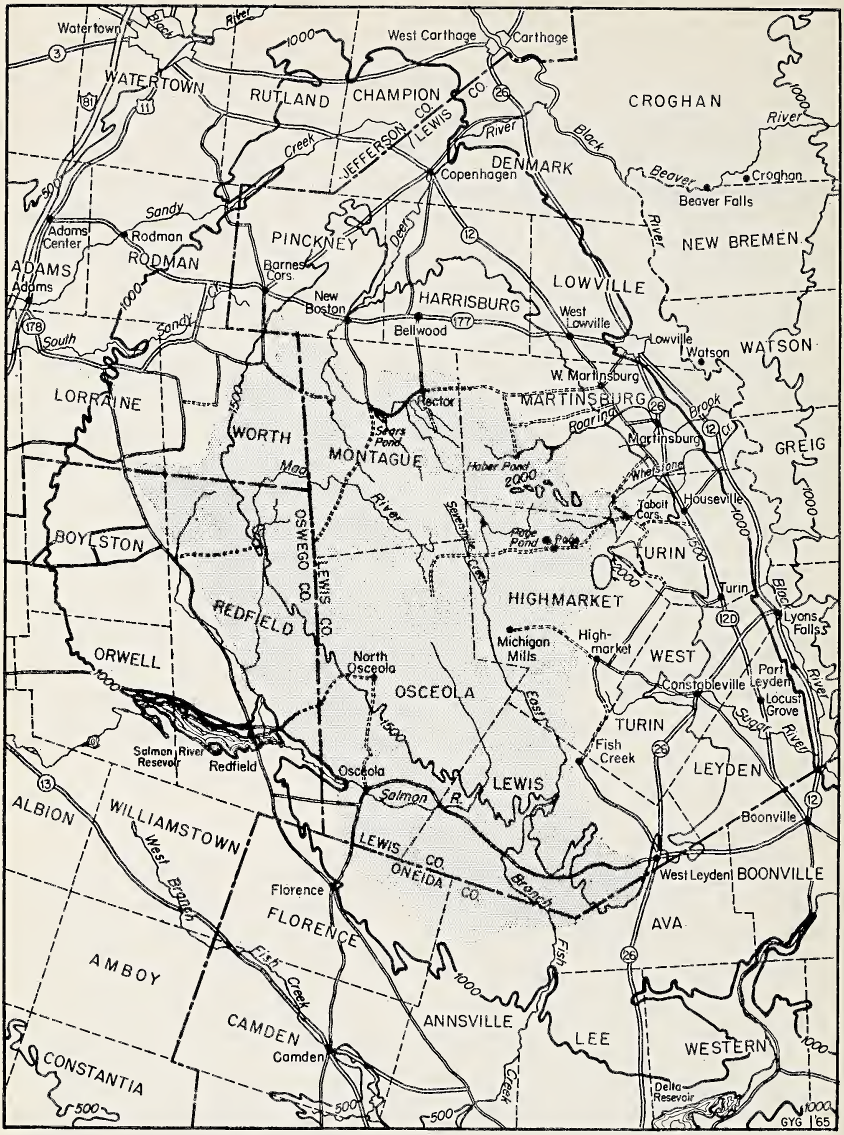
Winter of the Conservation Department. Urban Karcher, Lewis County treasurer, furnished bounty data for porcupines and other animals. John Heller of the State Museum and Science Service prepared the photographs and Mrs. Charles Gillette drew the maps for this publication. William A. Sheffer and Herbert Gerhardt of Syracuse granted us free use of a building on the slope of the plateau above West Martinsburg for laboratory purposes. The author, of course, is responsible for any errors or omissions in this report, and would be glad to hear from persons with additional information on the mammals of Tug Hill.

Description of Region

TUG HILL LIES MAINLY in western Lewis County, but continues at lower elevations into southeastern Jefferson County, northeastern Oswego County, and northwestern Oneida County (Map 2). The approximately oval-shaped plateau, flat to gently rolling on top, with a gradual slope on most sides, has a maximum length of about 50 miles, extending from the Black River Valley near Watertown in a southerly direction to the vicinity of the Delta Reservoir near Rome, and encompasses roughly 1,000 square miles. Although relatively small compared with other major natural subdivisions of New York, Tug Hill for several reasons may be considered a distinct and separate unit of the State. In some ways it resembles the Adirondack Mountains to the east, and in other ways the Appalachian Plateau region to the south.

Physiography

Physiographically, Tug Hill is recognized as a distinct province, being an extensive highland mass clearly separated from neighboring provinces (Miller, 1924). On the southeast, the land slopes away to the upper Mohawk Valley; to the southwest and west, the slope is towards the Lake Ontario Plain; to the east, the valley of the Black River sharply separates the plateau from the Adirondacks, and also in its swing westward around the north end of the plateau from the St. Lawrence region to the north. Although the sides are mostly gently sloping, much of the eastern edge of the plateau proper is bounded by a steep shale escarpment about 400 feet high, below which the land drops down a series of flat, fertile limestone terraces or benches several hundred feet to the Black River (total descent about 1000 feet). Elevations in this province range from 500 feet on the lowest slopes to over 2000 feet. Land above 1900 feet in elevation is confined to a section about 12 by 5 miles extend-



MAP 2 TUG HILL PLATEAU

Most roads are shown, including secondary and dirt roads used in this study.

▨ Approximate extent of heavily wooded area

Contour interval 500 feet

5 0 5 Miles

ing from near the edge of the escarpment (west of Turin and Houseville) northwestward, to about the center of the plateau; this is the uppermost level or crest of Tug Hill, and is exceptionally flat, with only a few points rising to slightly above 2000 feet. North, south, and west from this section, the land continues to be quite level, gradually sloping away. Gomer Hill, 4 miles west-northwest of Turin, nearly 2100 feet high, is the highest point on the plateau. Several deep gorges or ravines, locally called gulfs, cut back into the edges of the plateau. Striking examples are the steep-sided, narrow, post-glacial ravines up to 300 feet deep in the shale of the high eastern escarpment, such as Roaring Brook at Chimney Point, and Whetstone Gulf, now preserved in a State park of the same name.

The upper reaches of Tug Hill, poorly drained due to the flat topography and relatively impervious subsoil, abound in marshes, swamps, bogs, and slow meandering streams, excellent habitat for many semi-aquatic mammals, although natural ponds are few. Most of the water finds its way to Lake Ontario, except for the extreme southeastern corner which drains into the Mohawk River. Major stream systems are Salmon River, including its tributary Mad River, Sandy Creek, and South Sandy Creek, all flowing west into Lake Ontario; Deer River flowing north, and many smaller streams flowing north and east to Lake Ontario by way of the Black River; and Fish Creek, especially the East Branch, flowing south to Oneida Lake, and then into Lake Ontario.

The rock formations resemble those of the Appalachian Plateau and are unlike those of the nearby Adirondacks, which are chiefly ancient, Precambrian metamorphic rocks. The Tug Hill sedimentary rocks are flat-lying strata of late Ordovician age. Several hundred feet of limestone rim the plateau at the base followed by about a thousand feet of shales, in turn capped by thin resistant sandstone over much of the upper part of the plateau. There is little exposed rock, aside from the ledges and cliffs in the gorges which cut back into the edge of the plateau. The thin, stony soil of the upper part of the plateau, derived largely from sandy shales and sandstones, is apparently intermediate in acidity between the Adirondack soils (from the more acidic granitic gneisses, etc.) and the soils of the northern Appalachian Plateau, which are often influenced by limestone and calcareous shale. This may be important in determining Tug Hill's distinctive flora, along with other factors, including climate (Hotchkiss, 1932).

Climate

The only weather station on the upper part of Tug Hill, where most of this field study was done, is at Highmarket, in Lewis County, on the eastern side of the plateau, and is at an elevation of 1786 feet. Precipitation is recorded, but not temperature. Here the average annual precipitation is over 50 inches (51.43 inches for the period 1931 to 1955—Johnson, 1960); this exceeds Lowville (37.05 inches), at 860 feet elevation in the Black River valley, and other localities at low elevations around Tug Hill. Additional details on precipitation, and other climatic information for stations at low elevations near Tug Hill are given by Mordoff (1949).

The climate is unfavorable for agriculture, with harsh conditions prevailing in winter and spring on the upper part of the hill, and with a short growing season in contrast to adjacent productive lowlands. Tug Hill is famous for its snow, and according to P. H. Stevens (*in* Johnson, 1960) its average fall is the greatest on record in the United States east of the Rocky Mountains, ranging from approximately 100 to 188 inches. Located in a snow belt at the eastern end of Lake Ontario, this cool upland area with its gradual slopes is exposed to the prevailing winds sweeping across the lake. The western slopes and upper levels receive and hold great quantities of snow over a long winter period.

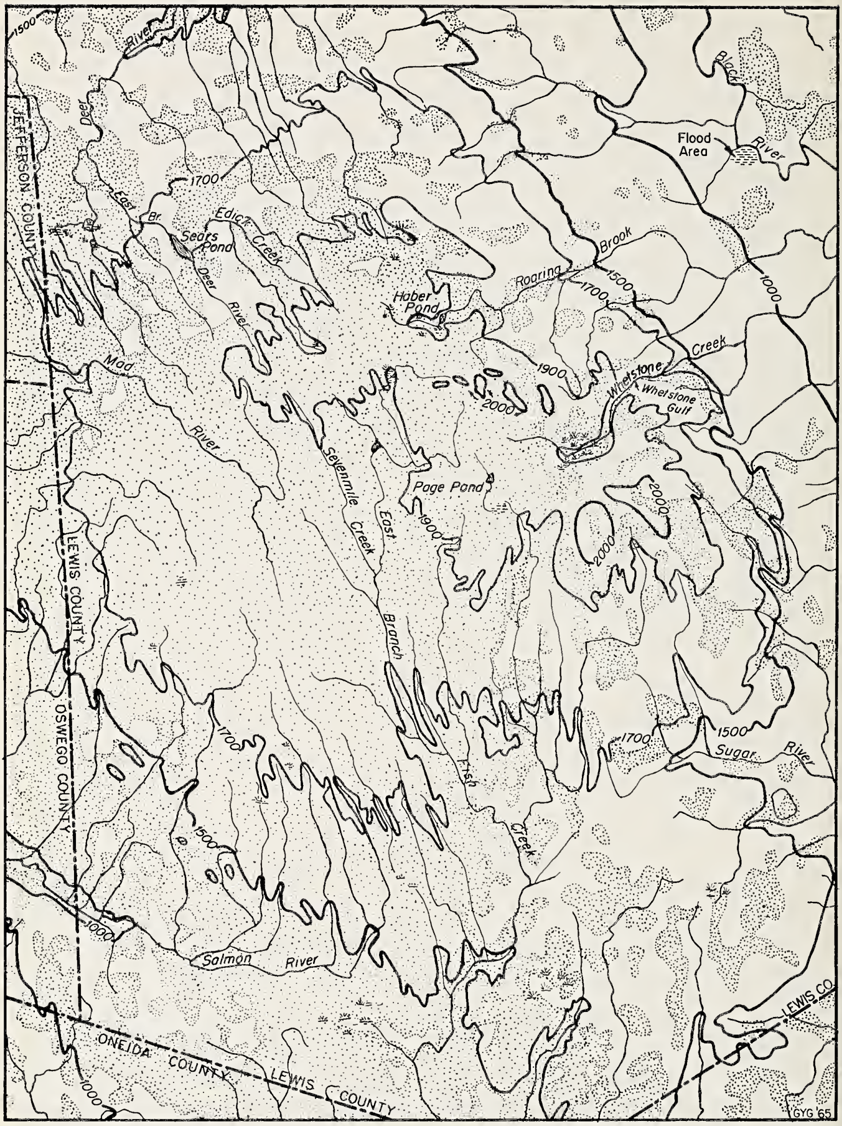
According to biweekly measurements of snow depth for five recent winters, 1958-63, which I have examined (Eastern Snow Conference, 1960-64) for Sears Pond, Lewis County (lat. 43° 44′, long. 75°43′; elevation 1740 feet), near where much of the mammal collecting was done, the snow, usually over 2½ feet deep in early January, reached its greatest depth (4 to 6 feet) during March in four of these winters. Approximately the same snow depths prevail at Highmarket, where measurements are made at 1800 feet elevation. Undoubtedly, some areas of the plateau are buried even deeper, and in addition, the strong winds create much drifting in the open. The snow creates transportation difficulties and it is not unusual for some of the rural areas and remaining farms to be snowbound for days at a time. The winter of 1959-60 brought much snow, with big storms on November 27, 28; January 4, 5, and 6; February 14; and February 26, 27; drifts 10 to 14 feet high on Tug Hill were frequently reported by highway officials.

In the length of its growing season, Hotchkiss (1932) concludes that the Tug Hill Plateau is more or less intermediate between the Adirondack Mountains and the northern Appalachian Plateau. Although there are no official temperature records for the upper part of the plateau, it has a cool, brief summer with an obviously short frost-free or growing season, probably well under 120 days. Hotchkiss (1932) describes the effects of this short season on the native vegetation, including apparently a frequent lack of mature fruit in the woods, both on forest trees and early spring herbs. Mammals and other animals are undoubtedly affected too, by the deep snows and severity of the climate, and probably by the resultant effects on the vegetation. Some mammals found in the general region are absent or uncommon on the upper level, while others do well there.

The relative backwardness of the weather on Tug Hill became especially apparent to me in winter and early spring, 1960, when I was afield in the vicinity of Sears Pond and Edick Creek (elev. about 1740 feet). Here, the snow in the woods according to my measurements, reached a maximum depth of about 4½ to 5 feet by the third week of March. After this, it began to recede, but was still 3 feet deep on April 4, and 1½ to 2 feet deep in mid-April; by April 29, the woods were largely free of snow, though snow lingered in patches on north-facing slopes well into May. The streams in this same area remained mostly ice-bound until after the first week of April. During the first half of April, the contrast observed in traveling the few miles up from the Black River Valley to this area of the plateau was striking; with spring in full force down below, Tug Hill presented a white and frozen aspect, with frequent cold winds, strong snow squalls, and drifting snow. The hill was strangely quiet, too, because the early migratory birds had not yet moved up from the lowlands, and the early frogs, coming into chorus in the valley, were not yet active.

Vegetation and Habitats

An extensive forested block of northern hardwoods interspersed with spruce and fir occupies most of the upper level of the plateau, with over two-thirds of the area above 1500 feet being wooded, while the surrounding lowlands are largely agricultural. Around the edges of this forest are many acres of abandoned, and some of occupied farmland, abandoned fields being frequent as high as 2000 feet altitude along the high eastern margin of the plateau. The first white settlers arrived in the general region in the 1790's, with a systematic but only partially successful effort being made to settle the high plateau wilderness between 1840 and 1846 (French, 1860; Hough, 1872). Former farmland, much of it abandoned since 1900, is slowly reverting to woods. The primary occupation of the few remaining farmers on the plateau is dairying. The central forested



MAP 3 DETAIL OF TUG HILL PLATEAU

Small mammal-collections were made in this area.

▨ Woodland cover

5 4 3 2 1 0 5 Miles

section, although never cleared, has been subjected to lumbering throughout. Much of this area today is dense second-growth woods with trees of small size classes, and with many small streams and swamps often densely covered with alders. Stout (1958) states that most of the hardwood trees today, which outnumber the conifers more than formerly, run heavily to decay, crook, and other forms of unuseable cull, and are slow growing.

Several authorities have classified the vegetation of Tug Hill in relation to that of other areas. Bray (1930), in an account of the vegetation of New York, places upper Tug Hill, along with most of the Adirondacks and Catskills, in his Zone D or Canadian-Transition Zone, which he describes as characterized by trees dominant in Zone C, the next lower zone (Allegheny-Transition Forest of sugar maple, beech, yellow birch, hemlock, etc.), plus red spruce, balsam fir, and paper birch (although the latter is rare on Tug Hill), by an increase in more northerly herbaceous plants of the forest floor, and by the absence of oaks, hickories, and other southern species. Hotchkiss (1932) explains that Bray's Zone D, which seems to correspond with the Canadian Zone of Merriam (1898), covers nearly all of the plateau above 1500 feet, and some of it below this level, especially on the west and south sides; below this is a gradual intergradation with Zone C (=Merriam's Transition Zone). Missing from the plateau are Bray's Zone E, or his Canadian Zone, occurring only at higher elevations in the Adirondacks and Catskills, with spruce, balsam fir, and paper birch dominant, and Zone F, the arctic or alpine summits of a few high Adirondack peaks. Hotchkiss observes that the vegetation of Tug Hill resembles that of the nearby Adirondacks, but seems to be more closely related to the geologically similar Appalachian Plateau, since more Tug Hill species of plants are held in common with the main plateau to the south than with the Adirondack Mountains.

Braun (1950), places the plateau in the Adirondack Section of the northern Appalachian Highland Division of the extensive Hemlock-White Pine-Northern Hardwoods region. The Adirondack Section is described as embracing the Adirondack and Tug Hill uplands, where red spruce is one of the dominant forest trees, and the surrounding lowlands. Smith (1954), in mapping the primeval forests of New York, shows the plateau top in Spruce-Fir-Adirondack Hardwoods (a subdivision of the Spruce-Fir Forest); the remainder of the area is classified as Adirondack Hardwoods, with a Hardwoods-Spruce-Fir subdivision covering most of the plateau, and Hardwoods in the fringe areas and Black River Valley.

Hotchkiss (1932) gives a list of the plants of the climax forest of the higher part of the Tug Hill Plateau. The principal trees are yellow birch, beech, and sugar maple, with red spruce, red maple, American mountain ash, hemlock, balsam fir, black cherry, etc., also present; among shrubs, hobblebush *(Viburnum alnifolium)* is especially abundant. An area of original virgin forest still in existence in 1927, as described by Hotchkiss, was a stand of hardwoods and conifers which was quite open beneath, with many trees having a diameter of three feet or more, and a dense ground cover of herbs, but with fewer shrubs than usual in the cut-over woods. In spite of the logging, the same author does not believe the forest has been disturbed enough to make it differ greatly from the virgin climax forest, although red spruce was more common originally. Other conspicuous habitats discussed by Hotchkiss include the gorges, abandoned agricultural land, marsh meadow (frequent along upper courses of the streams), swamp shrub (alder abundant), swamp forest (red maple, balsam fir, etc.), bog meadow (sphagnum, sedges, etc.), and bog forest (black spruce, etc.). The decomposition of organic matter is generally more rapid than in the Adirondacks, thus not favoring such an extensive development of duff mats (raw humus or mor) and bogs, but at least partial bog conditions are common on the upper part of Tug Hill *(ibid)*.

Armstrong (1954) in a generalized forest map of Lewis County, based primarily on aerial photographs, shows northern hardwoods covering most of Tug Hill, but with irregular patches of spruce-fir types liberally scattered over the higher part of the plateau. In traveling across the wooded upper level along the lumber road west of Page, elevation 1800 to 1950 feet, I noticed that the ground, although nearly flat, was slightly rolling in a series of low ridges. The higher ground was covered with hardwoods, especially yellow birch, red maple, sugar maple, beech, and black cherry, with occasional conifers, namely red spruce and balsam fir, rarely hemlock. The lower ground was wet, often boggy, and usually covered with shrubs or conifers (spruce, tamarack); the many streams were bordered with woods, alders, or grassy meadows.

Altitudinal range covered in the field work was from 1950 feet in the east-central part of the plateau down to 730 feet in the Black River Valley. Most of the collecting, however, was done above the 1700 foot contour line, a nearly circular, mostly level area 15 to 20 miles in diameter, lying almost entirely in western Lewis County, about in the center of the plateau (see Map 3); about 75 percent of this area is wooded, and includes most of the wilderness area mentioned in the Introduction, plus high, mostly abandoned farmland on the eastern and northern edges. This, primarily, is the area I have often referred to as the top, or central region, or upper part, level, slopes, reaches of the plateau, etc. The unbroken, densely wooded and swampy part of this area is sometimes alluded to as the heart or interior of the Tug Hill woods, or the central forested section. These woods extend in a nearly continuous block further west and south into the three adjoining counties to below 1500 feet. As defined in Stout (1958), this 85 percent wooded district is the forested heartland, or Central Tug Hill sub-region which covers 200,000 acres, and has less than 100 inhabitants. Although the boundaries do not coincide, the area above 1500 feet, extending further north and east and including a few small villages, also encompasses an area of roughly the same size. These additional areas might well be considered as part of the central region, and although including lower elevations and more irregular topography, the weather, vegetation, and other conditions are probably closely similar, and as mentioned above, this is approximately the area of Bray's Zone D or Canadian-Transition zone. Below about 1500 feet, and below the eastern escarpment, are the lower slopes, and peripheral, fringe, or marginal areas of the plateau, including the limestone terraces mentioned previously. Bordering the plateau are the adjacent lowlands, especially those of the Black River Valley and Lake Ontario Plain, which, extending south to north on either side of Tug Hill, are natural routes west of the Adirondacks for certain species that have spread northward in recent years.

An effort was made to trap all of the major habitats harboring small mammals. Various woods were investigated, the most intensively trapped type being dense woods characteristic of the interior of Tug Hill, consisting of the northern hardwoods with conifers, usually red spruce and balsam, mixed in. Partiality was shown to the more mature sites where the undergrowth was more penetrable and where small mammal signs and tunnels were usually more frequent. Also, collecting was done in woods chiefly beech and sugar maple without conifers, and in several small coniferous stands, usually red spruce or balsam fir. Shrubs, particularly hobblebush, ferns, small herbaceous plants, and fallen logs and branches were frequent on the ground in the woods, but sedge and grass was generally scarce except along trails and roads. Considerable trapping was conducted along the banks of streams in wooded and swampy areas. Several bogs were investigated, both of the sedge-shrub (bog meadow) and the coniferous (bog forest) types. Traps were also set in abandoned grassy and bushy farm fields and pastures, and in and around old farm buildings, bridges, and culverts. Rocky habitats covered included the rocks and small boulders along several of the streams, and the edges of the exposed beds of sedimentary rocks in several ravines. Some of the collecting areas are shown in the photographs (Figures 1-14).

Accounts of Mammals

OPOSSUM

Didelphis marsupialis virginiana Kerr

Not many years ago, the opossum was unknown as far north as the Tug Hill region, but our native marsupial has been persistently extending its range northward. Within the last two decades the opossum has been reported from a number of new localities from all sides of Tug Hill, placing this region within the northern limit of its range (see Hamilton, 1958; De Vos, 1964). We did not encounter the opossum on Tug Hill or note any road kills in the area, but Conservation Department files indicate that rabies control trappers employed to trap foxes in this general region, between 1949 and 1962, reported captures of one opossum each in the Tug Hill townships of Florence (1954), Lorraine (1953), and Montague (1952). In addition, Hamilton (1958) indicates that six were trapped in Florence in 1951, with no prior reports from that area. Florence, with a range in elevation of about 600 to 1200 feet, is in Oneida County on the south-western fringe of the plateau, while Lorraine, range about 600 to 1300 feet, is on the western slope, in Jefferson County. Also, Conservation Officer Don McIntosh reported the occurrence of an opossum in the fall of 1964 in Rodman, north of Lorraine, under 1000 feet altitude, another peripheral record (J. E. Wilson, *pers. comm.*). The record for Montague in Lewis County is the only one I know of for the central, elevated part of the plateau. Elevations in Montague, in which Sears Pond is located, range from about 1600 to 1900 feet, with almost all of the area either in dense forest or abandoned farmland. Winter conditions are severe. It seems highly unlikely that the opossum, which prefers lowlands and must forage for food all year, will become common on the upper level of the plateau, or maintain itself in any numbers through the harsh winters that usually prevail there.

MASKED SHREW

Sorex cinereus cinereus Kerr

Specimens taken. 122

Distribution and habitat. This tiny shrew seems to be at home in all the major habitats of the plateau. It occurs throughout the dense, typical Tug Hill woods of spruce, fir, yellow birch, beech, maple, hobblebush, ferns, wood sorrel, etc. Masked shrews also were encountered in deciduous woods, in swampy woods under fir and red maple, in open fields and meadows, in alder swamps, along the banks of streams, and in sphagnum bogs under shrubs and sedges. Along the stream banks more smoky shrews and water shrews were taken, but elsewhere *cinereus* outnumbered the other species of *Sorex*. Specimens were collected between 1550 and 1950 feet altitude, except for three taken along with smoky shrews in hemlock-hardwoods at 750 feet, next to the Black River (most of the trapping was done at the higher plateau elevations). In winter on Tug Hill, a few were trapped in woods on top of deep snow, where their tiny holes and tracks were noted.

Food habits. Fifty stomachs were examined, chiefly from spring, summer, and fall, and three from winter. The principal food was insects, both adults and larvae, while other invertebrates and a small amount of plant matter comprised the rest. Percentage of total volume, followed by the occurrence by number of stomachs (in parentheses) follows.

Insects, 85.1 percent (50); spiders, 5.8 percent (4); centipedes, 2.7 percent (4); undetermined invertebrates, 4.6 percent (4); plant material, 1.9 percent (2). Breakdown of the insect food is: Lepidoptera (larvae), 26.7 percent (16); Coleoptera (adults), 14 percent (8); Coleoptera (larvae), 3.2 percent (3); Diptera including Tipulidae (larvae), 5.6 percent (6); Hymenoptera (ants), 1 percent (1); Orthoptera, 1 percent (1); unidentified insects (adults), 23.2 percent (23) and (larvae), 10.4 percent (10). One stomach in August was three-fourths filled with spores of the fungus, *Endogone*.

The only seasonal difference apparent concerns the 15 specimens from June (from woods and bogs at 1820-1930 feet elevation). In these, the food was predominantly caterpillars (Lepidoptera), which occurred in 12 of the stomachs, was the only food present in 8, and comprised 74.3 percent of the volume.

Reproduction. Two females collected in early April appeared inactive reproductively; the first sign of breeding noted was a female on April 21 with enlarged uterus. Five females with embryos were collected from May 12 to July 7. The first juvenile out of the nest was taken June 21. Six nursing females were recorded between May and August 11. Adult males in evident breeding condition were collected from mid-April to the first week in October. Litter size based on 5 embryo and 2 placental scar counts average 6.0 (range 4-7); embryo size ranged from 1.5 mm. (diam. of swellings) to 11 mm. (crown to rump length).

Measurements. Sixteen adult males collected from April to July average: weight, 4.8 grams (4.4-5.6); total length, 103.5 mm. (100-113); tail, 42.3 mm. (38-45); hind foot, 12.2 mm. (11.5-13). Thirteen nonpregnant adult females from April to July average: weight 4.9 grams (3.8-6.8); total length, 105.0 mm. (97-113); tail, 41.5 mm. (38-45); hind foot, 12.0 mm. (11-12.5). Nursing females were the heaviest in the group.

SMOKY SHREW

Sorex fumeus fumeus Miller

Specimens taken. 90

Distribution and habitat. The smoky shrew was less numerous on Tug Hill and was found in fewer habitats than the masked shrew, except along stream banks in the woods, where more smoky shrews were taken than any other species of shrew. Here, this species sometimes comprised 20 percent or more of the total small mammal catch. Of those traplines where one or both of these two species of *Sorex* were collected, more *fumeus* were taken on 15 traplines (*fumeus* only, on 11,) and more *cinereus* on 26 traplines (*cinereus* only, on 21). Nine of the traplines catching more *fumeus* were set along stream banks. In this habitat, under woody cover of one kind or another, 48 smoky shrews, 24 water shrews and 11 masked shrews were taken.

Along the watercourses, smoky shrews were trapped chiefly in cavities in the shady banks, under the overhanging roots of trees and stumps, and among moss-covered rocks. On the plateau by such streams as East Branch Fish Creek, Edick Creek near Sears Pond, and Sevenmile Creek, smoky shrews were trapped in the same situations with water shrews. But unlike the water shrew, *fumeus* evidently is attracted to the cavities and rocky labyrinths along the banks because of something else in the environment than the water itself, since this species is not aquatic and elsewhere in its range is often common in, although not confined to, rocky areas and talus slopes in the woods.

The smoky shrew was encountered locally in mixed coniferous-deciduous, and beech-maple woods, being found about stumps and logs, and in tunnels in the leaf mold in these habitats; it was scarce in swampy situations, and was not collected in bogs or open fields and meadows, habitats where the masked shrew was often common. Nearly all of the specimens were trapped between 1700 feet and 1950 feet on top of the plateau, where most of the trapping was done, but the species occurs at all elevations in the region.

Food habits. Insects (61.5 percent) and earthworms (31.0 percent) were principal foods in 24 digestive tracts from the plateau in April, June, July, November, and December. Percentages of total volume of food items, followed by occurrence in parentheses, is: earthworms (Lumbricidae), 31.0 percent (12); Coleoptera (adults), 11.3 percent (5); Coleoptera (larvae), 3.3 percent (2); Lepidoptera (larvae), 5.3 percent (2); Diptera (larvae), 3.8 percent (3); thrips (Phloeothripidae), 2 percent (1); Formicidae, 1.2 percent (1); unidentified insects (adults), 30.4 percent (14); unidentified insects (larvae), 4.2 percent (3); slugs, 1.7 percent (1); spiders, .2 percent (1); unidentified invertebrates, 6.7 percent (4); vegetation, .6 percent (2). The large numbers of earthworms eaten seems noteworthy, since Hamilton (1941) found earthworms to be insignificant in the diet of this shrew.

Most of the smoky shrews examined were taken along the banks of four streams frequented also by water shrews. But, the diet of the two species differed markedly along the same streams at the same time of the year, based on these limited samples. Smoky shrews evidently dined primarily on terrestrial insects and earthworms here; water shrews examined contained no earthworms, but otherwise fed on a greater variety of forms, including many aquatic insects, and also various other animals, such as those perhaps more common in damp situations close to the water's edge (see Water Shrew; food habits). Also, the fungus *Endogone* was not detected as a food of smoky shrews in this Tug Hill sample, although it was noted in several of the water shrews.

Reproduction. Relatively few adult females were collected (sex ratio of catch 1 female: 2.5 males). No females were collected before April 16, but three females taken April 16 to 21 showed preparation for breeding by enlarged reproductive tracts. On April 23 one was carrying 7 tiny (1 mm.) embryonic swellings. Data on four others: May 4, seven embryos at 13-15 mm. crown to rump; July

6, lactating; July 19, seven embryos at 12 mm. crown to rump; and October 3, a late-breeding female indicative of recent nursing and with placental scars present. The first young of the year was trapped on June 24, although undoubtedly some were out of the nest well before this date. All 25 adult males taken from April to July indicated breeding condition (testes about 5-7 mm.); 24 young and subadult males from summer, fall and winter were non-breeding (testes less than 1.5 mm.).

Molt. Most of these shrews collected in April were still in full gray winter coat, although a female on April 23 had already begun to molt, with brown summer fur already in below and up along the sides; this would soon spread up over the back. Another on May 4 had nearly completed the molt. Yet as mentioned by Hamilton (1940) the spring molt may be long postponed for some individuals, and such evidently was the case for two adult males on June 9 and July 6, which showed unusually sharp demarcation on the back between the brown summer pelage anteriorly and the gray winter fur remaining on the posterior of the back; several others taken in this period were in full summer coat. Few specimens were collected in early autumn, but molting in October was suggested. A male on October 17 was in the process of molting to the winter pelage, while two females on October 27 and October 29 had completed molting (as had all 14 individuals from November).

Measurements. Twenty-two adult males (April-July) average: weight, 9.2 grams (8.1-11.3); total length, 122.8 mm. (122-130): tail, 47.0 mm. (44-51); hind foot, 13.6 mm. (12.5-14.5).

WATER SHREW
Sorex palustris albibarbis (Cope)

Specimens taken. 33

Distribution and habitat. Water shrews are found chiefly at higher elevations in New York, in the Canadian and Canadian-Transition zones. Along the many waterways of the Tug Hill Plateau, this small semi-aquatic mammal is probably as numerous as anywhere in this State, although not previously reported from west of the Black River. Other main centers for this shrew in New York are the Adirondack and the Catskill mountains. There are several scattered records elsewhere for eastern New York, and it occurs in Allegany State Park. Little has been written on the habits of *Sorex palustris* in the northeast. However, John G. New *(pers. comm.)* of the State University College at Oneonta, New York, is conducting a study, as yet unpublished, of the water shrew in the Catskill Mountains. On Tug Hill, we collected water shrews at eight localities, all in Lewis County, and within a 22 mile stretch from north to south across the center of the plateau. In the north, one was taken 9 miles west of Lowville on the northern edge of the main forested area of Tug Hill; at the southern limit three were trapped 6 miles west of West Leyden, less than two miles from the Oneida County line. Unquestionably the species extends west from the plateau center into similar country in northeastern Oswego County and the southeastern corner of Jefferson County, and probably also down into the western part of Oneida County above Oneida Lake.

Twenty-six water shrews were collected in the drainage system of East Branch Fish Creek, which drains much of the high central part of the plateau before flowing south to Oneida Lake. The remaining 7 were taken in territory drained by the Deer River, which flows north to meet the Black River. Water shrews are undoubtedly to be found in similar country along the upper reaches of the Mad River, which drains much of the western side of the plateau. Several shorter streams which drain the eastern edge of the plateau and then drop through spectacular ravines, such as Roaring Brook and Whetstone Creek, were trapped without success, but it is logical to suppose that water shrews occur in favorable places along the upper parts of these streams.

On the Tug Hill Plateau, this species was not restricted to any particular type of stream or woodland cover, though most numerous in the heavily wooded higher part of the plateau, and probably scarce on streams in dry ravines and abandoned farmland. Both swiftly flowing and quiet waters were frequented. On Tug Hill, too, these animals sometimes wander away from the proximity of water and thus are probably quite capable of moving across country between streams, which are not far apart on the poorly drained summit, as well as moving along parallel to the waterways. Captures were made in a bog 175 feet from, and in woods up to 100 feet from, the nearest bodies of water—distances considerably greater than that given in most published reports on sites of capture of this aquatic shrew.

Seventeen of the specimens were trapped along large rocky-bedded streams in the woods, 7 along a small, slower alder-lined stream, 6 in woods and marshy spots near a pond, 2 in a bushy sphagnum bog, and 1 in the open under grass along a tiny intermittent creek.

Elevations ranged from 1300 to 1940 feet. The remainder of this section provides details on the various habitats where water shrews were collected.

Large streams. Fourteen water shrews were trapped on East Branch Fish Creek, its tributary Sevenmile Creek, and Edick Creek, a tributary of Deer River, above Sears Pond (Figures 5, 6, 7, 8). Conditions appeared similar along these moderately swift, rocky-bedded, sizable streams 10 to 35 feet wide, varying in depth and swiftness of current locally and seasonally. Here the water shrews were taken in traps set from 2 inches to 8 feet from the water's edge. Two or three were caught at water level along the flat shore, where traps were shaded by weeds or shrubs. Most, though, were caught more than 3 feet from the water's edge, and 2 feet or more higher than the level of the water along the low sloping banks characteristic of these streams. The stony and often moss-covered banks, usually set back a few feet from the water's edge, provided cover in the way of many natural cavities and passageways, and with an abundance of sheltering roots, fallen logs and stumps. Water shrews were taken along such streams above 1700 feet elevation in the woods of red spruce, fir, hemlock, yellow birch, sugar maple, black cherry, etc., but the sites of capture were not correlated with any particular type of overhead tree cover, coniferous or otherwise. The stony to muddy shore zone between bank and stream usually had a growth of sedges, weeds, and alders, or other shrubs. Other small mammals, including mice and shrews, especially *Sorex fumeus,* frequented the same stream banks with *palustris.*

Thirteen miles downstream and 400 feet lower on E. Branch Fish Creek from the situation as described above was a somewhat different sort of habitat. Here (west of W. Leyden, elev. 1300 feet) the stream is 80 to 100 feet wide and rushing, with frequent rapids and small waterfalls. Three water shrews were trapped on flat, shelving limestone rock next to clefts and cavities at the foot of a high precipitous north-facing slope clothed with hemlock, hardwoods, yew, and ferns. The shrews had to cross up to several yards of flat, exposed rock to reach the water in this area, evidenced in the aquatic insects included in their diet. This bedded limestone contrasted with the small, loose sandstone rocks of the stream beds higher up on the plateau.

Water shrews haunt the stream banks at all seasons. Although the catch was concentrated in July (not until July, 1960, was the upper E. Branch Fish Creek drainage intensively covered, where most of the specimens were taken), several were caught in the preceding winter on swiftly flowing Edick Creek. Here six were caught between mid-November and March, three of these being taken in December and March under snow 1½ to 3 feet deep, a few feet from the stream, which was mostly covered with ice. Even when the traps were carefully tended, there was a marked drop in the catch of all small mammals along the banks of this stream in spells of severe weather, especially blizzard-like storms combined with low temperatures. Possibly the animals tended to remain back more in the cover of the woods during such weather.

Small streams. Small, quiet, meandering creeks on the flat upper level of Tug Hill apparently create good water shrew habitat. Most of these are densely "choked" with alders and human access is difficult. One, a small tributary of E. Branch Fish Creek, was trapped beginning where one bank had been partially cleared near a woods road, and yielded the largest catch of water shrews per length of shoreline. Seven (3 adult males and 4 immatures) were taken along 200 feet of stream bank July 12-19 (500 trap nights); five of these were taken along a 50 foot stretch at the end of the trap line (Figure 9) where the alders were dense and where traps could be set only by walking in the middle of the creek. The stream was 5 to 8 feet wide, 1 foot deep or less at the time, stony-bottomed, but overlaid with silt where the alders were dense. Aside from one captured under a small bridge where the bank was partly cleared of bushes, the animals were taken within 6 inches of the water's edge, along a stony and muddy shore only a few inches wide, in the shelter of dense alders, among and under the reclining stems, and in moist cavities at the base of these shrubs. Woods were nearby, but this trapping suggests that water shrews may be common along many miles of such alder-lined waterways on the plateau, the alders apparently providing adequate cover.

One water shrew was collected in October about 100 feet from spruce-fir woods beside an intermittent marshy stream 1½ feet wide, a few inches deep, and nearly hidden under dense grass. This was the smallest stream where this shrew was collected and the only site of capture removed from tree or shrub cover.

Ponds. Ponds are few on the plateau aside from some small bog ponds and beaver ponds, but trapping during July around a large pond at Page, 6½ miles west of Houseville, produced 6 water shrews. The surrounding region is forested, chiefly deciduous: beech, maple, etc., with some spruce and fir. Beavers were present in the area. Five of the specimens were trapped under trees 10 to 100 feet from the water, in tunnels and holes in the humus, and under roots; three of these were on a wooded peninsula nearly an island, about

200 x 75 feet in size, surrounded by water except for a flooded marshy neck on one side, and two others under stumps in the woods 100 feet from the edge of the pond, near a damp sedgy opening. The sixth shrew was caught at the edge of the pond under bushes, in a low damp spot. No water shrews were taken at two smaller woodland ponds trapped.

Sphagnum bog. Two water shrews were taken in a sphagnum bog during July at a tunnel opening in the moss under 2 to 3 foot high bog rosemary *(Andromeda glaucophylla),* Labrador tea *(Ledum groenlandicum),* and willow, with scattered black spruce nearby (two masked shrews were caught at the same burrow). The nearest body of water was 175 feet away, a typical bog pond with encircling zones of sedges, shrubs, and conifers (Figure 11). The nearest stream was Deep Creek, 500 yards away. One shrew had an empty stomach, but the other had eaten a salamander, aquatic beetles, and water mites.

Food habits. Table 1 summarizes 25 stomachs examined, of which 21 were from July and August and four from November and December. Reference collections of aquatic and shore organisms from one pond and two stream localities aided in identifying the items. About two-thirds (67.8 percent) of the food by volume consisted of insects, which were found in all but two stomachs; the remainder was chiefly vertebrates (11.2 percent) and invertebrates other than insects (7.3 percent).

In the few studies that have been made of food habits of this shrew, in different parts of the country, both terrestrial and aquatic organisms have been found in the diet, but in varying proportions. The findings here somewhat resemble those of Conaway's (1952) comprehensive study in western Montana, in which aquatic insects were found to comprise a large part of the diet of *Sorex palustris navigator.* In our Tug Hill sample, 40 percent to 50 percent or more of the volume was aquatic organisms, their presence indicated in 18 to 20 or more of the 25 stomachs examined. This indicates frequent entry into the water for food; also, aquatics were present in stomachs from all the main habitats covered: swift and slow streams of different sizes, pond, bog, etc. Sixteen stomachs contained strictly aquatic nymphs and larvae, such as Plecoptera (stoneflies), Ephemeroptera (mayflies), Trichoptera (caddis flies), etc., as determined by the gills and other structures present. Included were swift current forms, such as the stoneflies, Heptageniidae, and *Hydropsyche.* Many of the beetles were aquatic types probably caught in the water. Some insects were not definitely determined as aquatic or terrestrial, such as Tipulidae (crane fly) larvae, many of which

TABLE 1
Stomach analyses of 25 *Sorex palustris* from the Tug Hill Plateau, New York, 1959-60

Food	Percent of volume	Occurrence (number of stomachs)
INSECTS		
Ephemeroptera (aquatic nymphs; especially Heptageniidae)	12.2	8
Tipulidae (larvae; aquatic or semi-aquatic?)	8.8	4
Lepidoptera (larvae)	6.0	5
Trichoptera (aquatic larvae, including *Hydropsyche*)	5.8	7
Coleoptera (adults; including aquatic Hydrophilidae and/or Dytiscidae)	5.8	7
Coleoptera (larvae; including aquatic forms)	5.8	7
Plecoptera (aquatic nymphs)	2.8	2
Diptera (adults)	2.5	2
Diptera (larvae)	.8	2
Hymenoptera (adults)	.4	1
Megaloptera (aquatic larvae; including *Chauliodes)*	4.8	3
Unidentified insects	11.5	14
Insect eggs? (Hemiptera?)	.6	1
OTHER INVERTEBRATES		
Phalangiidae (Harvestmen)	4.4	7
Spiders (especially Lycosidae, also 1 Thomisidae)	1.8	4
Hydracarina (water mites)	.2	5
Isopoda (Oniscoidea, probably *Oniscus*)	.8	1
Mollusca	.1	2
VERTEBRATES		
Mammals (including probably bait in 1)	7.6	2
Salamanders	3.2	2
Fish (Cyprinidae)	.4	1
PLANTS		
Endogone	5.0	5
Miscellaneous vegetation	.7	6
OTHER		
Unidentified materials	4.0	7
Rolled oats (bait)	4.0	1

are semi-aquatic, living in moist ground near water. The lycosid spiders seemed to be the same kind which I frequently saw running along the margins of the streams (*Pirata* sp. ?). Water shrews on occasion catch small fish, and the scales, pharyngeal teeth, and other parts of a minnow in one stomach probably indicates an instance of this.

This large shrew is quite voracious, and probably will feed on any small vertebrate it can catch and overcome. Perhaps it occasionally catches small mammals in the manner of *Blarina,* as there were instances in this study of feeding on carrion, at least. A water shrew caught in a trap set for weasels, by a small stream in an open grassy area, had its stomach filled with the remains of a meadow mouse, probably from one used as bait; but the mouse was missing, possibly dragged off by another water shrew. In another locality, a water shrew's stomach was 90 percent filled with the remains of *Blarina.* On the trapline, *Blarina* was not trapped or used for bait, thus it was not determined whether the water shrew had found it dead or had possibly killed it. In two other streamside localities, where *Sorex palustris* was the only shrew taken, two or three partially eaten water shrews in traps probably were fed upon by others of the same species. Also, partly eaten meadow, red-backed, and jumping mice in traps were believed to be the work of this shrew in some instances. Re-setting a streamside mouse trap which had been found to contain a badly-eated *Microtus* resulted in the capture of a water shrew within a few hours.

Plant items were probably accidentally consumed, except for the subterranean fungus *Endogone,* masses of spores of which were found in the alimentary tracts of several from stream banks, and in one specimen forming over 50 percent of the contents of stomach and intestines. This material has not previously been recorded as food of the water shrew, but has been reported in the diet of certain other shrews, namely *Blarina, Sorex cinereus* and *Sorex fumeus* (Diehl, 1939; Hamilton, 1941; Whitaker, 1962; this publication) and seems to be eagerly sought out by many small mammals. Small twigs and bits of bark in several stomachs may have been from caddis fly cases partly swallowed along with the insects.

Little seasonal information was obtained, since most specimens were from summer. But three of four water shrews from Edick Creek near Sears Pond in late November and December contained primarily aquatic Ephemeroptera nymphs (100 percent, 90 percent, 70 percent), plus other insects including Plecoptera nymphs in one, and the remains of a small fish in another (the fourth contained only rolled oats bait). Thus, the water shrews were apparently still drawing heavily on aquatic foods during this period. The ground at the time was covered with snow, winter-like conditions had set in, and when the last specimen was trapped December 12, most of the stream was frozen over (my records do not indicate if it was this latest one that had eaten only the bait). Yet it would seem logical to expect fewer aquatics in the diet during hard-frozen conditions.

A live water shrew, kept for a day and a half in a cage, avidly ate beetles and the flesh of *Blarina* and *Microtus*. Snails and ants were ignored. It readily plunged into a large bowl of water set in the cage flush with the surface of a layer of moss, leaves, etc., and caught and ate both land beetles floating on the surface and several aquatic diving beetles.

Remarks. Only rarely were "signs" noted in the wild that indicated the presence of water shrews. Careful scrutiny of the shoreline in several places where these shrews were present revealed numerous indistinct small footprints and droppings, probably made by water shrews as well as other small mammals. Twice I saw tiny wet footprints on flat stones beside streams, perhaps indicating where water shrews had recently emerged. In the fine silt under the alders along the little quiet creek where water shrews were numerous both small footprints and rather large, elongated shrew scats were frequent, undoubtedly evidence left by the water shrews.

Mouse snap traps, with wooden pedals and mixed peanut butter and rolled oats bait, were used in collecting all except two specimens, one of which fell into a sunken can placed in the ground under a log near a stream, and another which was taken in a rat trap baited with a mouse, as previously mentioned. Many of the captures were made at night, but several were definitely known to have been trapped by day, indicating diurnal as well as nocturnal activity.

A water shrew taken alive at 11 a.m. on July 13 was heard to spring a trap behind me just a few minutes after I had set it by the bank of a stream. The shrew was held by a hind foot only and was attempting to retreat into a small cavity in the bank next to which the trap had been set. When picked up, the shrew bit me on the hand, pinching sharply and hanging on in bulldog fashion, but failing to pierce the skin. Placed in a cage, it was active, ate, and seemed normal for a day and a half before dying (autopsy revealed internal injuries, possibly from the trap). When a bowl of water containing live insects was placed in its cage, the shrew swam, dove, and caught the insects, as mentioned above, and it also seemed to enjoy running back and forth across the surface of the water without seeming to break the surface film, as described by Jackson (1928) and others.

Reproduction. Only two breeding females were collected: a late-breeding one on July 30 had four small (3 mm.) embryos, with evidence of recent lactation, indicating this was not its first litter of the season; another on July 13 was nursing. Nine other summer and autumn females were non-breeding young of the year.

All adult males, those born in the previous year, were collected in July, except for one badly damaged early spring specimen. All nine of the July adults were in breeding condition, with enlarged reproductive structures, including testes 6 to 7 mm. long, and conspicuous side glands covered with a dense growth of short white hairs. Eight young males in their first summer (July, August) were inactive reproductively, with very small testes at about 1 to 1.5 mm. The summer juveniles of both sexes also differed markedly from the adults in less tooth wear, lighter weight, pelage differences as mentioned below, and slightly swollen and well-haired tails, tufted with hairs at the tip, in contrast to the relatively bare tails of the adults. Two young males were collected in December, one of which on December 2 had small testes as above, but another on December 12 showed some enlargement (2 mm.), conceivably indicating the start of unusually early sexual activity such as was shown by Conaway (1952) for this species in Montana. However, I have no additional information on this, since no males were collected in the winter after December 12.

Pelage. Molt was not satisfactorily studied because of a lack of specimens from around the year; most of the skins are from July, plus a few from August and late autumn. Ten young of the year from summer (July 7 to August 13) are uniform in appearance and show no sign of molt. Dorsally, they are comparatively dull and somewhat browner than any of the other specimens; below the fur is brown, and nearly as dark as the upper parts. Five immatures taken later in the year (October 23 to December 12) are altogether different, having evidently already molted into the winter coat. In these, the fur is longer and darker (more blackish), but with an iridescence or shine; the under parts are now much lighter, mostly of a silvery or whitish hue, just slightly tinged with brown.

In contrast to the summer young, the 10 July adults preserved as skins vary greatly in the condition of their pelage. Two females (July 13, 30) appear to be in summer pelage: although slightly darker, the general appearance is more like the summer young than any of the others, the fur being short and brownish, and dark below (in one about as dark as on the dorsum). The adult males are in a different pelage or are molting. Four (July 8 to 27) are in winter (?) pelage and have long, lax, somewhat iridescent fur, and three of them are pale below; these individuals resemble the late fall immatures, although they are slightly paler and are the most "grizzled" of the lot (conspicuous light tips to the hairs). Four other males (July 1, 14, 15, 15) are molting, as indicated by sharply defined areas of two pelages. Each has a large area of shorter, apparently new, fur on the back. The longer fur, seemingly worn and resembling that in the non-molting males, occurs chiefly on the head, nape, and sides. Below, light silvery fur alternates with brown: two are mostly light, but are brown anteriorly, and one is all dark brown below except for small spots of longer silvery fur, giving a patchy appearance. Without specimens from other months I do not know for certain what this early summer molting of adults represents, except that in its time of occurrence, it apparently differs from any previously reported for the water shrew. This species is known to have a spring and fall molt; Conaway (1952) found the latter came early in Montana, chiefly in late July and August, with a pattern similar in both old and young animals, but all his adults taken from June to mid-July were in complete summer pelage.

Measurements. Nine adult males in July average: weight, 16.1 grams (15.3-17.0); total length, 157.9 mm. (149-162); tail, 70.8 mm. (64-74); hind foot, 19.0 mm. (18.5-20). Two July adult females average: weight, 14.3 grams (13.1-15.5); total length, 155.5 mm. (154-157); tail, 70.0 mm. (69-71); hind foot, 18.7 mm. (18.5-19).

Twelve other summer (July-August) individuals are non-breeding immatures in their first summer. Eight males in this group average: weight, 11.0 grams (10.0-11.9); total length, 151.5 mm. (146-153); tail, 71.1 mm. (67-75); hind foot, 19.1 mm. (18-20). The four females: weight, 10.6 grams (9.9-11.0); total length, 147.8 mm. (145-152); tail, 66.8 mm. (64-69); hind foot, 19.0 mm. (18.5-19.5). The few older immatures taken later in the year are similar in size. In weight, two males (December) average: 11.2 grams (9.8-12.5); four females (late October to late November): 10.6 grams (8.1-12.0).

PYGMY SHREW

Microsorex hoyi thompsoni (Baird)

No pygmy shrews were collected on Tug Hill, even though numerous sunken cans and mouse traps were placed in grassy situations resembling places in east-central and northern New York where the author has taken this species. However, years ago three were taken marginal to Tug Hill at Locust Grove, Lewis County (Merriam, 1895), this being the first known locality for *Microsorex* in New York according to Miller (1899). This shrew, the smallest mammal in our State, is rarely captured and may long exist undetected in a region. Although so far reported from only a few counties in New York, it probably exists in all of the counties except Long Island and the extreme southern part of the State. The few other known points for *Microsorex* in northern New York are at lower elevations than the upper reaches of Tug Hill, thus there is the possibility that conditions are unsuitable for the species on this elevated plateau, but it is more likely that the pygmy shrew does occur, at least locally.

SHORT-TAILED SHREW

Blarina brevicauda talpoides (Gapper)

Specimens taken. 214

Distribution and habitat. This common shrew is found in all types of woodland on Tug Hill, and its numerous shallow tunnels meander about under the fallen leaves; here it lives in company with the red-backed mouse and other small woodland mammals. *Blarina* is common, too, on the abandoned agricultural land on the plateau, where it often travels the *Microtus* runways and the large tunnels of *Condylura*. This shrew also was collected in alder swamps, along streams, and along old stone walls and in culverts. The only places intensively trapped that did not yield any specimens were the banks of four woodland streams and a large sphagnum bog covered with sedge and shrubs. *Sorex palustris* and *Sorex fumeus* were common along the streams mentioned, but along other streams, all three shrews were taken together. Short-tailed shrews were among small mammals flooded out of a meadow during a rise of the Black River in November 1959. This is detailed in the meadow mouse account.

Food habits. Stomachs of 46 individuals were checked, all but two from mid-June to early October, and about equally divided between forest and field habitats. No marked monthly or habitat difference in type of food was apparent. Major items were slugs and snails, insects, and earthworms, with percent of volume and occurrence as follows: slugs and snails, 33.1 percent (22); insects, 30.8 percent (14); earthworms, 18.0 percent (14); millipedes, 6.1 percent (6); unidentified invertebrates, 8.7 percent (16); vegetation, 3.3 percent (17). The insect food is as follows: Diptera (larvae), 18.7 percent (16); Coleoptera (adults), 5.9 percent (5); Coleoptera (larvae and pupae), 1.8 percent (3); Lepidoptera (larvae), 1.1 percent (2); unidentified adult insects, 4.3 percent (11). Plant food included numerous spores of *Endogone* in one stomach, the remainder being grass, dead leaves, etc. No vertebrate remains were detected, but several individuals were attracted to traps baited with meat for weasels.

Reproduction. Few breeding females were obtained. One on April 22 had 5 embryos (1.3 mm.), another on April 23 had 6 embryos (4 mm.); two nursing ones were collected June 23 and July 22 (latter with 6 placental scars). Adult males in apparent breeding condition were collected from April 5 to September 29.

Measurements. Average weight of 38 adult males: 20.4 grams (16.6-25.4). Twenty adult males average: total length, 125.5 mm. (117-131); tail, 27.0 mm. (22-29); hind foot, 15.1 mm. (14-16). Average weight of 40 nonpregnant adult females: 19.3 grams (14.6-23.9). Ten adult females average: total length, 127.2 mm. (120-135); tail, 28.4 mm. (26-31); hind foot, 14.7 mm. (14-15.5).

HAIRY-TAILED MOLE
Parascalops breweri (Bachman)

Specimens taken. 10

Distribution and habitat. Hairy-tailed moles were included in the catch at several localities on Tug Hill, at both high and low elevations. At the same time, this species and some other tunneling small mammals appeared to be scarce in many areas, perhaps indicating that the soil humus on much of the upper part of the plateau is unfavorable for tunneling, and is lacking in food. In some wooded areas, no tunnels of mole or vole size could be found. *Parascalops* was encountered primarily in the more friable humus of certain stands of relatively large deciduous trees: generally sugar maple, red maple, beech, and yellow birch, occasionally with scattered conifers. One wandering individual was trapped in what probably was a *Condylura* tunnel, in a moist field frequented by *Condylura* and *Microtus,* about one-third of a mile from the nearest woods. Usually *Parascalops* avoids wet and poorly drained areas, such as those which cover a large part of the upper level of the plateau, and which are often occupied by *Condylura.* Merriam (1884) caught several of these moles as well as star-nosed moles near his home at Locust Grove, Lewis County. He was mistaken, however, in including the more southerly eastern mole *(Scalopus aquaticus)* in the fauna of this region.

Food habits. Percentages of total volume of food items in the stomachs of seven summer and fall specimens from upper part of the plateau above 1600 feet altitude are: Diptera (larvae), 46 percent; earthworms, 19 percent; Coleoptera (adults), 15 percent; millipedes, 8 percent; Coleoptera (larvae), 3 percent; spiders, 2 percent; centipedes, 2 percent. Each of the above occurred in two or more stomachs; minor items, each found in small amount in a single stomach include: ants, ant pupae, Coleoptera pupae, insect eggs?, and plant fragments.

Remarks. Near the Black River a hairy-tailed mole was caught alive by hand after it had been driven to a road, apparently out of an adjacent meadow, by a flood on November 7, 1959 (described in the meadow mouse account). At first the mole escaped by running off the road into the rising water and swimming on the surface of the water for several yards parallel to the edge of the road; soon it crawled up on the pavement again, but by then it appeared tired, and was easily picked up. It was not observed to dive and was, not unexpectedly, much less agile in the water than a star-nosed mole nearby which easily eluded me, although in this particular circumstance the hairy-tail may have been more exhausted.

Measurements. Seven adults average: weight, 61.6 grams (45.8-67.4); total length, 169.6 mm. (160-175); tail, 33.1 mm. (31-35); hind foot, 19.2 mm. (18.5-20).

STAR-NOSED MOLE

Condylura cristata cristata (Linnaeus)

Specimens taken. 17

Distribution and habitat. This partially aquatic mole is common in the moist environments occupying so much of the interior of the Tug Hill Plateau. Favored habitats here include marshy areas and damp meadows covered with sedge, grass, and scattered shrubs, situations commonly inhabited by meadow mice. *Condylura* also was found in bushy swamps, chiefly of speckled alder, covering many acres along the slower watercourses. Frequent signs of this mole in the damp soil included the large subterranean tunnels, sunken trench-like runways thinly roofed with vegetation, and mounds of thrown out soil. A few were trapped in boggy woods and along woodland streams. In these places, typical *Condylura* signs were less evident, and the animals were trapped next to logs, in cavities in the banks, etc. Several were seen by day running across the lumber trail in the woods west of Houseville. The star-nosed mole is common also in the low, moist land along the Black River, to judge from the numerous signs of their activity there.

Food habits. The stomach contents of 14 plateau specimens were examined. Earthworms (Lumbricidae), present in 11 stomachs, comprised about 65 percent of the total volume. Vegetable matter (leaves of sedge and grass, stems, rootlets, bits of moss) comprised 20 percent of the volume (11 stomachs). Aquatic organisms made up roughly 10 percent of volume, including aquatic or semi-aquatic crane fly larvae (Tipulidae: including *Tipula, Erioptera*) in 3 stomachs; several leeches (Hirudinea: possibly *Erpobdella*) in 1 stomach; small aquatic worms (Oligochaeta) in 1 stomach; and caddis fly larvae (Trichoptera) in 1 stomach. The remaining 5 percent (several stomachs) consisted of slugs and terrestrial insects, including Coleoptera (adults and larvae), and Lepidoptera (larvae).

Reproduction. Only three specimens indicated breeding, a female on April 7 with uterus enlarged, and two males April 8 with reproductive structures much enlarged. The first juvenile of the season (weight 39.4 grams) was collected June 8.

Remarks. The flooding of the Black River over its banks two miles southeast of Lowville on November 7, 1959, drove out of the meadows both species of moles, as well as many meadow mice and shrews (see also account of meadow vole). The hapless creatures sought refuge on a paved road which, for a while, remained slightly above the level of the flood waters, and I tried to catch a star-nosed mole which was found crouching in a crack on the edge of the pavement. When I approached, the mole swam out into the turbulent water, where it showed great agility in swimming and diving and was much too quick for me to catch it; but it remained nearby, swimming back and forth within a foot or two of the edge of the road and avoided swimming out into the deeply flooded meadow.

Measurements. Ten adults average: weight 55.7 grams (48.3-59.8); total length, 199.8 mm. (193-205); tail, 79.1 mm. (74-85); hind foot, 27.6 mm. (26-29).

LITTLE BROWN BAT

Myotis lucifugus lucifugus (Le Conte)

Specimens taken. 3

Distribution and habitat. This species is probably the most numerous bat on Tug Hill during the summer. In the evenings, small groups of half a dozen or so *Myotis* were occasionally observed hunting high and low over the streams, ponds, and marshes of the plateau. One each, taken from three such groups in August, proved to be this species. Most of the bats seen were probably this same species, although it is likely that some *Myotis keenii* were present too. In mid-summer on the upper level, few bats were seen, aside from these small groups of *Myotis*. These bats were active on the plateau at least until September 22, when a group of three were observed, and until mid-October or later at lower elevations in the valley. A lone *Myotis,* probably a male of this species, lived in a crack in the side of a house near Lowville; it was seen emerging in the evening as early as May 2 and as late as September 21. No summer breeding colonies were located on the hill, in spite of visits to many old buildings, but breeding colonies undoubtedly occur in the region, at least at lower elevations. Summer colonies of small bats reported from attics in nearby Boonville and Copenhagen are probably referable to this species. In occasional visits since 1957, David C. Gordon (*pers. comm.*) has found up to 60 or more bats of this species in winter, hibernating in Glen Park caves near Watertown, to the north of Tug Hill. Other recorded localities for areas marginal to Tug Hill include Locust Grove and Lyons Falls (Miller, 1897).

Measurements. Two adult males average: weight, 8.3 grams (7.4-9.2); total length, 92.5 mm. (90-95); tail, 40 mm. (38-42); hind foot, 10 mm. (10-10); ear from notch, 16 mm. (15-17); tragus, 6.8 mm. (6.5-7); forearm, 37.0 mm. (36.5-37.5); wingspread, 257.5 mm. (252-263).

SILVER-HAIRED BAT

Lasionycteris noctivagans (Le Conte)

The silver-haired bat was not collected, but it probably occurs, at least locally, on Tug Hill in summer. Probable sight identifications of several individuals of this species were made in August 1960, near the marshes bordering the upper part of Whetstone Creek, above the ravine. Only small bats of the genus *Myotis* and a few *Eptesicus* were seen during several evenings spent elsewhere on the plateau. Merriam (1884) refers to this species as by far the commonest bat in the Adirondacks and also at certain nearby localities along the Black River, such as at Lyons Falls and the junction of the Sugar River. As far as my observations go, this would not be the case for Tug Hill at the present time; but I made no observations at the Black River localities mentioned by Merriam.

BIG BROWN BAT

Eptesicus fuscus fuscus (Palisot de Beauvois)

Specimens taken. 1

Distribution and habitat. The one collected, an adult male, was found flying around just before dawn, in August 1960, inside our house, in the valley three miles southeast of Lowville. During this same month, several big brown bats were seen at twilight hunting over woods and streams on the top of Tug Hill at an altitude of 1900 feet, as well as in the Black River Valley. David C. Gordon (*pers. comm.*) has found small numbers of big brown bats in recent winters in Glen Park caves near Watertown. *Eptesicus* has apparently increased in this general region of northern New York since the time of Merriam's (1884) report on the Adirondacks, which included the area of his home at Locust Grove. He spent much time collecting bats, but he records only a single specimen from Lewis County, and refers to this species as unquestionably the rarest bat in the Adirondacks and vicinity.

Food habits. The captured bat had recently been feeding, and its digestive tract contained the remains of many insects of the orders Coleoptera, Lepidoptera, and Hemiptera. Also, several of what appeared to be ant pupae were present in the stomach.

Measurements. The single individual had the following dimensions: weight, 15.8 gms.; total length, 118 mm.; tail, 44 mm.; hind foot, 11.5 mm.; ear from notch, 19 mm.; tragus, 7.5 mm.; forearm, 43 mm.; wing spread, 310 mm.

RED BAT

Lasiurus borealis borealis (Müller)

Although I made several field observations of bats which were apparently this species during August and September evenings near the Black River south of Lowville, the red bat was not detected on Tug Hill. Here it is probably uncommon or local, as it seems to be in much of the Adirondacks, although its range extends northward into Canada. Perhaps this bat is most numerous in the region during migration.

HOARY BAT

Lasiurus cinereus cinereus (Palisot de Beauvois)

This large bat, generally considered an uncommon and local species, was not seen on Tug Hill, although most likely it occurs in small numbers in the warmer months. It is fairly common in some areas of central and northern New York, where I have observed it during the late twilight of summer evenings; because of its late emergence, it often goes undetected in the dark. Merriam (1884) reported that Dr. A. K. Fisher shot a large female, which had recently given birth, near Locust Grove, Lewis County, on June 30, 1883; this locality is on the Tug Hill fringe or bench area, as mentioned previously, between the Black River Valley and the main eastern escarpment of the hill.

VARYING HARE

Lepus americanus virginianus Harlan

Specimens taken. 11

Distribution and habitat. Abundant on Tug Hill during this period, varying hares or snowshoe rabbits seemed to be everywhere in the woods. These northern animals are, of course, well adapted to traveling over the deep snows of the area. They were especially numerous in woods with plenty of young coniferous growth, and in and near the edges of alder swamps—frequent situations on the plateau. This was the most frequently-seen mammal by day along the old logging route west of Houseville through Page and the heart of the forest. In winter, tracks and trails of varying hares in the deep snow were the most often noted and conspicuous of mammal signs. Woodlots in the valley east of the plateau were occupied by hares too, but more sparingly.

Food habits. Fresh signs of browsing in the winter of 1959-60 in the vicinity of Sears Pond indicated considerable feeding by varying hares on all of the following trees and shrubs: red spruce, yellow birch, sugar, red, and striped maples, alder (*Alnus rugosa*), and bramble (*Rubus* spp.). The evidence, consisting especially of pruned twigs, showed feeding by the hares on twigs, buds, needles, and bark of branches; twigs and needles from the tops of young spruce trees above the snow were heavily browsed, as were the twigs from young 5 to 6 foot high yellow birch saplings, while the canes or stems of *Rubus* were eaten. The stomachs of three late December specimens from this area all had a strong coniferous odor and apparently consisted entirely of the foliage and woody twigs of red spruce. I noted in early April 1960, that the level of much of the past winter's browsing was 3½ to 4 feet above the surface of the three foot deep, receding snow, and thus about 6½ to 7 feet above ground level; much old browse from the previous winter was 5 to 6 feet above the ground.

These animals feed on tender parts of many plants in summer. I made few observations at this season, but on the top of the plateau, west of Houseville, observed varying hares feeding by day along the side of the trail on white clover (*Trifolium repens*), Common Plantain (*Plantago major*), and other low plants. Stomach of three July specimens contained the leaves of grass or sedge and other herbaceous plants.

Measurements. Four adults average: weight, 1,831.5 grams (1623-2070). Two adults (females) average: total length, 526.0 mm. (507-545); tail, 43.5 mm. (37-50); hind foot, 151.0 mm. (147-155); ear from notch, 82.5 mm. (80-85).

EASTERN COTTONTAIL
Sylvilagus floridanus mearnsii (J. A. Allen)

Cottontails were seen north of Tug Hill, in Jefferson and Lewis counties, as well as in the Black River Valley and near the shore of Lake Ontario during this study, but not on the plateau proper. No cottontails were noted in early morning and evening drives through various types of cover from open field to forest in the upper sections of the plateau, although many varying hares were seen. However, cottontails have been reported from a number of peripheral areas including the Lewis County towns of Harrisburg (some observed, 1964) and Pinckney (two killed by hunters, 1964) (J. E. Wilson, *pers. comm.*); these towns are on the northern slope of the plateau above 1000 feet altitude. Although there has been an increase in their numbers in northern New York in general in recent years, Smith (1954) suggests that the few cottontails that presently occur in the peripheral areas of Tug Hill may disappear as the land continues to revert to forest. Cottontails from out of State have been released at Watertown and elsewhere, but I assume it is the native form which predominates in this area.

WOODCHUCK
Marmota monax rufescens A. H. Howell

Woodchucks were encountered throughout the region. Besides being numerous all around Tug Hill, the animals were common in the fields and woodlots at high elevations bordering the large central forested section. Also, woodchucks occasionally were seen near the center of the Tug Hill forest several miles from any open habitats, aside from marshes and bogs. On the upper part of the plateau, above 1700 feet altitude, woodchuck tracks were first noted in the snow late in March 1960, but the animals did not appear to spend much time above ground until mid-April. In the period 1949 to 1962 hundreds of woodchucks were captured by State fox trappers in their sets on Tug Hill, including all townships of the region.

EASTERN CHIPMUNK

Tamias striatus lysteri (Richardson)

Specimens taken. 34

Distribution and habitat. The chipmunk was the most numerous member of the squirrel family on Tug Hill during this survey, occurring throughout the wooded and brushy areas, except in excessively swampy areas. It was often common in woods where no tree squirrels could be found. Along the logging road west from Houseville across the center of the forested area, chipmunks were ubiquitous, and were a close second to the varying hare as the most frequently seen mammal by day. Chipmunks were conspicuous, too, in the dry woods along the rims of the deep ravines of Whetstone Gulf, Roaring Brook, etc. Most of the specimens were collected in deciduous and mixed coniferous-deciduous woods, under beech, maple, yellow birch, spruce and fir.

Hibernation. Chipmunks sleep in their burrows through the long winter season on Tug Hill, and although mild spells are known to bring these animals out for a look around, no outside or above snow chipmunk activity was detected here for about six months, in 1959-60. Dormancy began in October, and no chipmunks were observed on the elevated plateau from late in that month until about the end of the third week of April, when they were noted as active in several areas. Undoubtedly some chipmunks made forays earlier in the month, but the deep snow that persisted into April 1960 probably restricted their outside activity over much of the plateau until after the middle of this month. The snow was officially 57.6 inches deep at Sears Pond and 59.0 inches at Highmarket on March 16 (E. Snow Conference, 1960b), a time when chipmunks are often active above ground in many parts of the State. On April 7 it was spring-like in the valley and a few chipmunks were up and about there, with increased activity by April 12, but it was still wintry on Tug Hill (cold, windy, deep snow almost everywhere in the woods). On April 13, in an area near Sears Pond which I visited almost daily in April, snow was still a good 1½ feet deep throughout the woods, and still no chipmunks in evidence. During the third week of the month, a warm sun finally broke the grip of winter here, and starting about April 20, chipmunks were out in numbers; April 22 was the date of the earliest one collected.

Chipmunks are known to remain below ground also during hot spells in summer. No marked period of dimunition in activity was noted on the hill in this season, and the animals were out in numbers every week during the warm months.

Food habits. Twenty stomachs from May, June, and July were examined. Plant food, chiefly nuts and seeds comprised about three-fourths of the volume, while the remainder consisted primarily of insects. The following percentages are of total volume, followed by occurrence in parentheses. *Plants*—nuts and seeds, especially maple seeds, 63.0 percent (19); fungi, 3.5 percent (2) (including *Endogone* in 1); green leaves, 3 percent (1); apples (probably all bait), 7.5 percent (4). *Insects*—Coleoptera (adults), 7.5 percent (9) (including *Phyllophaga,* may-beetles, in 2); Coleoptera (larvae), .8 percent (2); Lepidoptera (larvae), 7.9 percent (9); unidentified insects, 5.4 percent (7). *Other animals*—earthworms, 2.0 percent (1); slugs, .3 percent (1); bird (feathers only), .5 percent (1); unidentified, 1.1 percent (2). Fragments of maple seeds were identified in most of the stomachs; cheek pouches in summer very often were full of maple seeds from which the wings had been removed, and 223 red maple seeds were counted in the pouches of a single chipmunk, on June 17.

Measurements. Average weight of 20 adult males is 91.0 grams (80.9-106.4). Ten adult males average: total length, 249.8 mm. (242-259); tail, 95.0 mm. (89-101); hind foot, 37.2 mm. (34-46). Five adult females average: weight, 90.0 grams (81.1-97.8); total length, 245.4 mm. (242-252); tail, 95.0 mm. (90-97); hind foot, 36.0 mm. (35-37). Few females were collected (more than three males trapped for every female).

GRAY SQUIRREL

Sciurus carolinensis pennsylvanicus Ord

Although observed locally on all sides of Tug Hill, gray squirrels are confined mainly to lowlands in this general region. Frequently we saw them about the shade trees in residential areas in and near Lowville, and occasionally in woodlots and agricultural land not far from the Black River. A few were seen on the other side of the plateau in lowlands near the Salmon River Reservoir, Oswego County. This species was not recorded from the upper part of the Tug Hill plateau where most of the field work was done. A record for the western slope of Tug Hill is reported by Conservation Officer Don McIntosh, one having been taken during a recent fall hunting season in the Town of Worth, Jefferson County (J. E. Wilson, *pers. comm.*).

RED SQUIRREL

Tamiasciurus hudsonicus loquax (Bangs)

Specimens taken. 14

Distribution and habitat. Red squirrels were seen in various woodland habitats at all elevations. Yet they appeared to be scarce to only tolerably common in woods covering the upper reaches of Tug Hill during the period of this survey. In 1960, when much time was spent in this seemingly good habitat, red squirrels were only occasionally seen and rarely heard. Fluctuating as they do in abundance, red squirrels in other years may be more numerous. But a general scarcity of tree squirrels in this heavily timbered area was indicated; no grays, and red and flying squirrels neither observed nor trapped at many of the localities covered. In the same period red squirrels were noisy and plentiful, at least locally, on the lower slopes and in the valley. In Whetstone Gulf State Park the species was common; near the lower end of the gorge the animals were numerous in and near plantations of red pine, while above the gorge near the rim, large midden heaps of red spruce cones were frequent and conspicuous along the trails.

Some field observations. I often watched red squirrels near our winter headquarters in valley woods three miles southeast of Lowville. During subzero weather in January a red squirrel made frequent visits to a storage burrow which had been dug in soft, wet earth at the edge of a spring run, where the ground was not frozen and covered with snow as it was elsewhere in the vicinity. Several times this squirrel was seen to remove green, unopened white pine cones from the cache. The cones had been cut down before opening the previous year and storage in the wet ground preserved the cones with scales closed, holding the seeds in. The seeds were consumed in nearby trees, the scales littering the ground below.

Pellets under a barred owl perch in winter in the same woods indicated red squirrels were being eaten, and in early March a squirrel, perhaps the one observed retrieving the white pine cones, met such a fate near the spring. At 10:30 a.m. on a cloudy morning, a barred owl, evidently perceiving the ground-foraging activities of the squirrel, flew into a stand of white pines overlooking a burrow in the snow into which the squirrel had disappeared a few moments before (as far as I could determine from its leisurely actions, in order to search for food on the ground under the snow, not to evade the owl). From its perch the owl apparently could detect the squirrel below, because after a few minutes the owl suddenly plunged down feet first into the hole in the snow. For a moment only the tail of the owl was visible protruding above the snow, but then it emerged clutching the squirrel. After resting a moment on the snow, it flew off through the woods with its lifeless prey. Screaming blue jays, which had accompanied the owl all the while, failed to sufficiently alert the squirrel or hinder this daylight hunting activity of the owl.

Food habits. Observations made on the plateau and in the valley showed considerable feeding by red squirrels on mushrooms and on the seeds of red spruce, hemlock, and white pine; also feeding on the seeds of balsam fir, red pine, beech, and sugar maple was indicated. A few stomachs examined held mast, fungi, fruit, insect larvae (1 stomach), and trace of bird remains (1 stomach).

Measurements. Four adult males average: weight 194.7 grams (180.5-206.3); total length, 312.3 mm. (308-317); tail, 120.7 mm. (112-130); hind foot, 46.5 mm. (45-47). One adult female: weight, 176.2 grams; total length, 309 mm.; tail, 125 mm.; hind foot, 47 mm.

SOUTHERN FLYING SQUIRREL
Glaucomys volans volans (Linneaus)

The more southerly of the two species of flying squirrel was not taken by us on Tug Hill, where it probably occurs locally on the lower slopes but in all likelihood is absent from the upper level (the northern species was uncommon but presumably occurs throughout the area and at all elevations). But *volans* is not rare in this general region, even though it approaches the northern limits of its range here; apparently it is fairly frequent in the Black River Valley. The closest recorded locality to the plateau proper seems to be Locust Grove (Howell, 1918), in southern Lewis County west of the Black River on the Tug Hill fringe. Gordon (1951) collected a male *volans* in 1949 at Carthage, which is located on the Black River directly north of Tug Hill. Partially-eaten remains of a dead flying squirrel found three miles southeast of Lowville, near the same river, was tentatively identified as the southern flying squirrel.

NORTHERN FLYING SQUIRREL
Glaucomys sabrinus macrotis (Mearns)

Specimens taken. 7

Distribution and habitat. Unexpectedly, a rather low population of northern flying squirrels was indicated for the Tug Hill woods, at least in 1959-60. Trapping, as well as tracking in winter, suggested only local occurrence of flying squirrels on the plateau, and fewer than I have found in other years, using similar methods on hills and woodlots of Schoharie County (Connor, 1960), and at low elevations in scrubby woods of northern St. Lawrence County. Only two were collected in the densely forested central section of the plateau where most of the trapping was done. These were collected at two different localities, both at 1900 feet altitude. The others were collected on the eastern and southern slopes in fairly mature, mixed coniferous-deciduous woods (elev. 1150-1550 feet). All of the animals were caught on the ground under fairly large trees of various kinds (fir, spruce, beech, sugar maple). In a few places in winter, their tracks from tree to tree and tunnelings down through snow showed where they foraged, often under the protective cover of a dense secondary layer of young balsam fir and hemlock.

Although this scarcity may have been only temporary, the great depth of snow for a long period almost every year on the upper level may conceivably be responsible for restricting their numbers there, since even flying squirrels do much foraging and collecting of food on the ground. Possibly the dense, second-growth nature of much of the area at present, the result of lumbering, has made the area less suitable for flying squirrels than formerly. Frequent poor mast crops may be responsible. As mentioned elsewhere, all tree squirrels were comparatively scarce on the upper part of the plateau; chipmunks, on the other hand, were common.

Food habits. Six stomachs examined contained chiefly unidentified mast, also some fungi. Pieces of small roots in one specimen were perhaps accidentally eaten while getting food on the ground.

Measurements. An adult male, in breeding condition (June 21) weighed 103.8 grams; total length, 275 mm.; tail, 125 mm.; hind foot, 37.5 mm.; ear from notch, 23 mm. Three adult females average: weight, 94.7 grams (91.4-96.5); total length, 270.7 mm. (167-274); tail, 119.3 mm. (114-125); hind foot, 36.7 mm. (35-38); ear from notch, 28.3 mm. (23.5-27.5). The remaining three were immatures weighing 61.5 to 66.5 grams.

BEAVER

Castor canadensis Kuhl

According to Hough (1883) and earlier accounts, this plateau was originally renowned for its abundance of beavers and beaver meadows along the many sluggish streams. As elsewhere, heavy trapping pressure reduced their numbers until they became rare, and they probably disappeared entirely from the plateau sometime during the last century. Aided by introductions in the Adirondack region in the early 1900's, and a long period of protection, beavers have returned and are frequent once again along the wooded and swampy streams of the area. Houses and dams were observed by us on these and other Tug Hill waters and their tributary streams: Roaring Brook, Whetstone Creek, Sevenmile Creek, East Branch Fish Creek, Mad River, Deer River, Sears Pond, Page Pond and Haber Pond. American aspen, speckled alder, yellow birch, and red maple were frequently observed to have been cut down by beavers. Several dams seen in the alder swamps were constructed, aside from the usual mud and soggy materials, entirely of the boughs of alder.

DEER MOUSE

Peromyscus maniculatus gracilis (Le Conte)

Specimens taken. 117

Distribution and habitat. This is the common form of *Peromyscus* living in the Tug Hill woods, and only rarely was *leucopus* taken with it. In the numerous trap lines set out in the woods at 1900 feet elevation and above, *maniculatus* was taken exclusively. Several *leucopus*, collected with this species at one locality near Sears Pond at 1740 feet, were outnumbered in the catch by *maniculatus* by a 9 to 1 ratio. Also, on the southern slope of the plateau, *maniculatus* apparently was the common species in the woods at least down to 1350 feet altitude, where it was the only *Peromyscus* collected in two localities at this altitude.

Nearly all the deer mice were taken in rather deep woods, under the coniferous and deciduous trees and along streams. *Peromyscus* was scarce on abandoned farm land, at least at higher elevations on Tug Hill, since in considerable trapping in this environment only one was taken, an individual of this species, in a bushy hedgerow. A few deer mice were collected on most of the woodland trap lines, but often they were outnumbered by red-backed mice and sometimes also by jumping mice, as well as various shrews. Populations fluctuating as they do, in other years mice of the genus *Peromyscus* may be more abundant in the region.

Food habits. Fifty specimens of this species from the upper level of Tug Hill from June to November were examined. Plant matter (chiefly seeds and nuts) comprised 71 percent of the volume of the stomach contents, while animal items (mainly insects) made up the remaining 29 percent, as follows: *Plants*—unidentified seeds and nuts, 61.3 percent of volume (47 stomachs); fruit and miscellaneous vegetation, 8.7 percent (16); *Endogone,* 1.0 percent (1). *Insects*—Lepidoptera (larvae), 9.7 percent (18); Coleoptera (adults), 4.3 percent (12); Orthoptera, 1.8 percent (2); Formicidae, 1.4 percent (2); Coleoptera (larvae), .8 percent (1); Diptera (larvae), .3 percent (1); unidentified insects, 5.3 percent (23). *Other animals*—centipedes, 1.8 percent (1); spiders, .8 percent (3); mammal remains, 2.5 percent (5); birds (feathers), .3 percent (2). Little seasonal difference was noted except that caterpillars and fruit were eaten in summer. Six seeds or pits of wild black cherry were noted in the small cheek pouches of one of these mice; also *Peromyscus* caches of cherry and basswood seeds were found in the woods.

Reproduction. Eleven females carrying embryos and seven showing distinct placental scars were taken April 15 to November 24. Average number of young based on these counts is 5.1 (range 3-8); embryo size 2.5 mm. to 9 mm. crown to rump. Three females with embryos were still nursing earlier litters.

Measurements. Twenty adult males average: weight, 20.4 grams (17.5-23.6); total length, 185.5 mm. (171-199); tail, 94.2 mm. (86-103); hind foot, 21.1 mm. (19-23); ear from notch, 18.8 mm. (17.5-20). Twelve females without embryos average: weight, 21.5 grams (16.8-28.8); total length, 188.1 mm. (176-195); tail, 95.1 mm. (88-107); hind foot, 21.2 mm. (19-23); ear from notch, 19.2 mm. (17.5-20). A few of the individuals assigned to this form were difficult to identify at first glance in the field, especially some from the Sears Pond area (where both species occurred). These individuals tended to have somewhat small ears and short tails for the species, thus slightly resembling *leucopus*. Most characteristics of the pelage and skull, however, indicated *P. m. gracilis*. Three such adults from the Sears Pond area were omitted when the above measurements were compiled.

PRAIRIE DEER MOUSE

Peromyscus maniculatus bairdii (Hoy and Kennicott)

This distinctive subspecies, overlapping geographically with that of the preceding form, but ecologically separated—living in grasslands and open fields—has been taken only locally in New York, in three counties in the western half of the State. The most northerly, as well as the most easterly New York record so far, is at a low elevation on the shore of Lake Ontario at North Pond in northern Oswego County (Whitaker and Goodwin, 1960). This locality is only about 10 miles west of the 1000 foot contour line of the gentle west slope of Tug Hill. The Tug Hill forest to the east is a barrier to this mouse, yet it is possible that it exists sparsely in, or may in the future spread into, open country on other sides of this forested upland.

WHITE-FOOTED MOUSE

Peromyscus leucopus noveboracensis (Fischer)

Specimens taken. 8

Distribution and habitat. This species must have been extremely scarce in the extensive Tug Hill forest on the upper level, since it was not taken in much trapping at about 1900 feet elevation in this habitat. However, one was collected in a bushy sphagnum bog at 1830 feet within the upper forested region, about 10 miles west of Houseville. A few were taken on the eastern and northern sections of the plateau along rocky stream banks in woods near the edge of cleared land between 1740 and 1850 feet in altitude. This species was outnumbered by *maniculatus* at all localities where it was trapped on the plateau, except in the sphagnum bog, which produced no other specimens of *Peromyscus.* The white-footed mouse is common in fields in some regions, but we failed to find it in the high fields on Tug Hill during this period. At nearby low elevations off the plateau, such as the valley of the Black River, this species occurs, enters buildings, and may outnumber *maniculatus,* but too little trapping was done there to make any comparisons.

Measurements. Five adults (and subadults?) of both sexes from Tug Hill average: weight, 14.5 grams (14.0-15.2) ; total length, 164.8 mm. (151-181) ; tail, 78.8 mm. (68-87) ; hind foot, 19.9 mm. (19.5-20) ; ear from notch, 16.5 mm. (15.5-17.0).

RED-BACKED MOUSE

Clethrionomys gapperi gapperi (Vigors)

Specimens taken. 165

Distribution and habitat. Red-backed mice live in woods all over the Tug Hill Plateau, and in suitable woodlots at low elevations in the valley between the plateau and the Adirondacks, although not found in such great abundance as is often encountered in the higher Catskills and Adirondacks, and in the coniferous forests northward in Canada. Of the 30 woodland traplines on the plateau, this species was taken on 26 and comprised 10 to 57 percent of the total small mammal catch in these areas. Red-backs were found in various types of woods, as well as in small clearings and along streams, but the higher percentages usually came from the more developed stands of red spruce, balsam fir, beech, sugar maple, and yellow birch, with fairly luxuriant ground vegetation, hobblebush, fallen logs, stumps, etc. Quite likely the red-backed mouse was even more numerous under original conditions when spruce was more prevalent. On the plateau in winter their tracks were sometimes seen on the deep snow near stumps, fallen branches, and other low cover.

Food habits. Seventy-five summer, fall, and early winter stomachs from Tug Hill were checked over in a rather cursory manner for general feeding habits. Seeds and nuts were the chief foods, having been eaten by nearly all the individuals examined. Fruits were eaten in summer and included *Rubus* (blackberries and raspberries) and *Podophyllum* (may-apple). Green vegetation such as bits of moss, ferns, and unidentified stems and leaves were present in about one-fourth of the stomachs. Spores of the subterranean fungus, *Endogone,* were found in 14 specimens from July to November, and seemed to be a favored food, nearly filling the stomachs in several instances; small spores of an unidentified fungus were present in at least three others. Insects made up a small but probably regular part of the diet, occurring in small quantities in 17 individuals and representing each month (June to December) ; larvae of Lepidoptera and Diptera, and adult Coleoptera were the principal insects consumed.

Reproduction. Gravid and nursing females were collected from May 5 to September 30; litter size based on 12 embryo and 8 placental scar counts average 4.9 with a range of 3 to 7, and 5 the most frequent number of young. Few were collected in early spring, but males were already in breeding condition in late April; in autumn, several adult males collected in mid-September (and all taken thereafter) were in a regressed reproductive condition.

Measurements. Forty adult males average: weight, 21.1 grams (17.7-28.1) ; total length, 134.4 mm. (127-148) ; tail, 39.1 mm. (34-44) ; hind foot, 18.5 mm. (17-20). Thirty nonpregnant adult females average: weight, 21.1 grams (17.2-30.9) ; total length, 136.0 mm. (129-152) ; tail, 39.5 mm. (34-42) ; hind foot, 18.1 mm. (17-19.5).

MEADOW MOUSE OR MEADOW VOLE

Microtus pennsylvanicus pennsylvanicus (Ord)

Specimens taken. 352

Distribution and habitat. Meadow mice find favorable environment on Tug Hill in the many square miles of moist habitats and abandoned farm land. Approximately half of the catch was in meadows and old fields under heavy grass cover. Ninety were trapped along various streams flowing through the main forested section, among the grass, bushes, and rocks along the damp shorelines, and under the trees on the banks. In such situations the mice apparently conducted most of their activity in the narrow zone of suitable habitat close to the shoreline, and which may commonly serve as routes of travel through the woods for these animals. However, about 40 meadow mice were trapped away from streams, in woods where they seemed unlikely inhabitats; here they were sometimes in association with *Clethrionomys or Pitymys,* but occasionally were the only microtines found, dwelling in tunnels of their own under the dense shade of conifers, maple, beech, etc. Others were found living in small boggy places in the woods, where sphagnum, cinnamon fern, and a little sedge grew. Eighteen were collected in a large open sphagnum bog on the top of the plateau, under low sedges and ericaceous shrubs. Paths of the meadow mice, frequented also by masked shrews, traced over the sphagnum, but other mammals were scarce.

Microtus was apparently at a high level of abundance on the plateau in this period, especially in the fall of 1959, and into the winter. Possibly an overflow from the usual habitats accounted for the meadow mice in the woods. In the fall, many fields and meadows were riddled with their runways. The melting away of the deep snow in spring finally revealed the many signs of their winter activities: runways, tunnels, cores of earth which had been pushed into runways under the snow, surface nests, etc. At this time, too, I received complaints of winter *Microtus* damage in yards, especially to shrubs, from residents of small villages on the northern part of the plateau.

Information is lacking for this species on Tug Hill in the preceding winter (1958-59), but I understand that exceptionally high populations of meadow voles were reached at the time in lowlands in the northeastern corner of the State north of Tug Hill. Depredations of the mice under the snow cover as revealed in the spring came to the attention of many people. Apparently the mice were still numerous in much of that section in 1959-60, too, judging from complaints and reports in the local newspapers. So probably the abundance of these cyclic voles on Tug Hill at this time was closely if not exactly correlated with peak numbers in nearby lowlands.

Observations during a flood. It is not unusual, especially in spring, for the Black River to rise over its banks in places in its northward course along the eastern boundary of the plateau. One of the biggest and most rapidly rising floods I saw in the year spent living in the valley took place in autumn, on November 7, 1959, following torrential rains the previous day. A rich meadow of tall grass occupying most of the land inside a half-mile wide bend, or loop, in the river two miles southeast of Lowville (Map 3) was one of a number of low-lying areas inundated by the afternoon of November 7. Rising over its banks on the upstream portion of the bend, the water swept across to the downstream side, flooding most of the land between. On a low dike beside the river within the bend was a secondary road, on which I drove toward the downstream portion of the area at dusk. By then the flood-water, having in a few hours turned the meadow into a large lake, completely covering the grass, was nearing the top of the raised roadway. This was the last barrier to its re-entry into the river. Here I noticed that many small mammals were scurrying about on the edge of the road. Backing up my car to the safety of higher ground, I returned on foot with a flashlight.

Along the road, with water now flowing across it in places, were scores of desperate meadow mice. Water-soaked individuals stood on the road in an exhausted and dazed condition. Many of these could be approached and picked up, only feebly attempting to bite. while others were more active, returning to the water to swim and sometimes dive as I approached. Others huddled in small cracks along the edge of the pavement where water lapped at their feet. Still other voles had climbed up into large willow trees standing in deep water a few feet out from the road; singly, and in small clusters of two or three they held on to the rough bark a few inches above water level. Still others clung precariously in nearby bushes. Along the last 75 foot section of roadway before a stretch of water too deep for me to proceed, 13 meadow mice, two short-tailed shrews, one hairy-tailed mole, and one star-nosed mole were attempting to hide in cracks along the edge. Undoubtedly, nearly all of the animals observed, besides probably hundreds not seen elsewhere along the dike, were washed downstream into the river to perish from drowning or exposure. The water was very cold, the air temperature was below freezing, and a check later that night (also the next morning, see Figure 14) revealed the water washing over the road in a torrent all along the stretch where the animals had been. With a flashlight I was able to find only one mouse in the area, and mice were no longer clinging to the trees and bushes where they were seen earlier, although some may have continued to hang on, unseen in the dark. Thus, although no trapping was done here, it seems likely that this flood was severe enough to wipe out a large part of a high fall population of *Microtus* in this low-lying valley meadow.

Food habits. Food habits were not studied except to note from field signs that many grasses, sedges, shrubs and other plants were included in the diet, as is usual for *Microtus.* In many old fields on the plateau during this period meadow mice were feeding heavily in patches of orchard grass (*Dactylis glomerata*), where there was much evidence of their eating particularly the white basal parts of the leaves of this grass, just above the ground. Judging from numerous cuttings, they also fed under the snow in winter on the clubmoss *Lycopodium complanatum,* common in old fields and pastures of the area as well as in woods.

Reproduction. Fifteen females carrying embryos were collected between June 7 and October 5. Average litter size based on the 15 embryo counts and 7 placental scar counts is 4.9 (range 3 to 7); embryo size ranged from 5 mm. to 19 mm. crown to rump.

Measurements. The average weight of 65 adult males is: 35.8 grams (27.0-54.2). Twenty-five adult males average: total length, 166.4 mm. (147-186); tail, 51.9 mm. (47-61); hind foot, 21.0 mm. (20-22). The average weight of forty adult females without embryos: weight, 30.5 grams (23.0-47.8). Eighteen adult females without embryos average: total length, 159.5 mm. (150-181); tail, 49.2 mm. (44-58); hind foot, 20.8 mm. (19.5-22). The smallest juvenile trapped, recently out of the nest, weighed 8.9 grams.

PINE MOUSE OR PINE VOLE

Pitymys pinetorum scalopsoides (Aud. and Bachman)

Specimens taken. 6

Distribution and habitat. Six pine voles, all adults, were collected in woodland habitats at three localities in Lewis County on the Tug Hill Plateau. Four (3 in fall and 1 the following spring) were trapped six miles southwest of Lowville, at an elevation of 1900 feet, near Haber Pond (Figure 1). This was the northernmost locality.

The woods at this site were exclusively deciduous, primarily sugar maple and beech, with some yellow birch; the trees were relatively large for this region, but with evidence of periodic light logging. Stumps, logs, ferns, herbs, and seedlings were numerous on the ground, with some small patches of sedge and grass. Tunnels of hairy-tailed moles, shrews, and voles intersected under the leaf litter, all the pine voles being taken in the vole-sized passageways. Other microtines trapped in the same woods were a meadow vole and several red-backed mice.

Another pine vole was trapped in July near the shore of the large pond at Page, elevation 1940 feet; this was the highest and most "northern looking" of the three areas. The forest consisted of balsam fir, red spruce, beech, red maple, and hobblebush. Water shrews were common here. Farther south, also in July, one was taken five miles north of Osceola, at 1600 feet altitude, in mature mixed coniferous-deciduous woods where beech was abundant. Merriam (1885) recorded the species for the southern part of Lewis County at a lower elevation than the above Tug Hill localities, having captured one in 1884 near his home at Locust Grove; he considered *Pitymys* to be rare there, since he captured several hundred meadow voles before securing the specimen.

At the time of this field study, the Tug Hill locality six miles southwest of Lowville was apparently the northernmost for the State, being a slight extension north from Locust Grove. Since then I have collected pine mice to the north of Tug Hill and the Adirondacks in woodland areas in the St. Lawrence Valley region (northern St. Lawrence County). Thus the range of this southerly vole may be considered to extend through northern New York, even though its distribution may be spotty.

Food habits. Underground plant parts, consisting of roots and also the basal parts of the stems of grass or sedge, predominated in all of the 6 stomachs. Other items were green leaves of grass or sedge in 4 stomachs, fungi (probably mushroom) in 1, mast in 1, while small Diptera larvae, the only animal food noted, made up about one-fourth of the contents of 1 stomach.

Reproduction. All of the three females collected showed evidence of breeding. One on May 27 had 5 embryos, which measured about 20 mm. crown to rump. Another on July 14 showed 2 placental scars, while the third, on September 30, also had 2 scars and was lactating. An adult male on July 27 was in breeding condition, but two in October had regressed reproductive structures.

Measurements. Three adult males average: weight, 22.3 grams (20.0-24.3); total length, 118.7 mm. (118-120); tail, 21.0 mm. (19-

22); hind foot, 16.0 mm. (15-17). Three adult females (discounting weight of pregnant female) average: weight, 23.9 grams (21.2-26.7); total length, 124.3 mm. (118-130); tail, 24.3 mm. (22-26); hind foot, 15.8 mm. (15-17).

MUSKRAT
Ondatra zibethicus zibethicus (Linnaeus)

Muskrats are numerous along the many miles of waterways coursing through the woods and bushy swamps of the upper levels of the plateau. Their burrows are frequent along the banks of the streams, while houses and smaller feeding huts may be seen in the swamps and marshes and on the occasional small ponds. In the winter, the small feeding huts or shelters were sometimes noted out on the ponds, built on the ice. In the fall and early winter (1959), wandering muskrats were occasionally seen on the plateau in fields and along roads some distance removed from the usual aquatic habitat, although this is not unusual behavior for muskrats at this season and in spring.

NORWAY RAT
Rattus norvegicus (Berkenhout)

HOUSE MOUSE
Mus musculus Linnaeus

These introduced pests, occurring nearly everywhere about the habitations of man, are common in and near the farm buildings and small villages on the edge of the plateau. But they were not often found in the natural habitats in the wilder sections, where most of the trapping was done. Only one house mouse was taken at a distance from buildings. This was on the rocky, wooded edge of Whetstone Creek just above the gorge, at 1900 feet. No rats were captured in standard rat traps set primarily for weasels and squirrels in various habitats, but signs of rats were sometimes noticed along small streams and near barns in agricultural areas.

MEADOW JUMPING MOUSE

Zapus hudsonius (Zimmerman)

Specimens taken. 85

Distribution and habitat. Numerous on the Tug Hill Plateau, jumping mice of one or both species are found just about everywhere, perhaps because of the frequent moist situations producing abundant ground vegetation favored by these animals. *Zapus* was collected in three different kinds of environments on the hill: 26 were trapped in marshy habitats, usually under grass and alders growing along small, slow streams; 21 in abandoned farm fields and pastures among the grass, weeds, and scattered bushes; and 38 in various woods, often near streams and ponds.

In the typical mixed Tug Hill woods (away from the grassy, weedy growths by streams and ponds, and in clearings), *Napaeozapus* was frequently the only jumping mouse taken, although in at least two such wooded areas several *Zapus* were taken also. The greatest density for *Zapus* in any habitat was on a small island-like wooded peninsula (about 200 x 75 feet in size) in the large pond west of Houseville at Page (elev. 1940 feet); only a marshy neck covered with standing water connected it to the mainland. Sixteen *Zapus* were trapped at this unusual site between July 14 and July 21, under beech, red maple, hobblebush and young spruce and fir, along with 3 *Sorex palustris* and 7 *Microtus; Napaeozapus* was not present. This pond is located in a heavily wooded section, but there were some grassy, marshy areas nearby, which were probably inhabited by meadow jumping mice.

Food habits. Fifty stomachs were examined from animals collected in June, July and August. In this sample, plant material, chiefly seeds, made up four-fifths of the volume of food, while invertebrates. primarily insects, comprised the remainder. Further breakdown is as follows: *Plants*—seeds (mostly unidentified), 48.8 percent of volume (37 stomachs); *Endogone,* 8.5 percent (14); fruit, 2.8 percent (6); green plant matter, 2.8 percent (3); flowers, 1.4 percent (2); unidentified fungus spores, .4 percent (1); unidentified vegetation, 15.5 percent (21). *Invertebrates*—Lepidoptera (larvae), 14.1 percent (18); Coleoptera (adults), 2.6 percent (9); Diptera (larvae), .4 percent (2); unidentified insects, 2.6 percent (5); earthworms, .1 percent (1). Little monthly difference in major food items was noted in this limited sampling.

Hibernation. The earliest specimen of this small hibernator collected was a female on May 4, near a small creek at 1750 feet elevation, near where two woodland jumping mice were collected on the same day. Little information was obtained on fall disappearance. The last *Zapus* was trapped September 2, but little trapping was done in *Zapus* habitat the following three weeks. Coverage of seemingly good habitat in late September and October produced no specimens, possibly suggesting early disappearance of individuals in this area.

Reproduction. First litters of the year were indicated by four females with embryos June 8 to 15, and by 10 additional females lactating or with placental scars (or both) June 15-August 9. Five of the nine females which were nursing also carried small embryos (July 1, 19, August 9), indicating their second litters on the way. Two non-nursing females with large embryos were collected July 21 and August 13. The first young encountered out of the nest were three taken on July 14, each weighing about 10 grams. Sixteen embryo and placental scar counts average 5.3, and ranged from 3 to 7. Size of embryos ranged from small swellings 2 mm. in diameter to 16 mm. crown to rump.

Measurements. Fifteen adult males without hibernation fat average: weight, 19.3 grams (16.9-21.2); total length, 217.4 mm. (204-234); tail, 131.1 mm. (125-142); hind foot, 31.7 mm. (29-34). Fifteen females without hibernation fat average: weight, 20.6 grams (17.5-25.8); total length, 218.7 mm. (200-239); tail, 132.6 mm. (113-145); hind foot, 30.9 mm. (28-32). Six females with small embryos, 4 mm. or less, are included; heaviest ones in the group were several lactating and without embryos.

WOODLAND JUMPING MOUSE

Napaeozapus insignis insignis (Miller)

Specimens taken. 74

Distribution and habitat. *Napaeozapus* apparently occurs at least sparingly throughout the woods of this region. Many were collected in woods and along woodland streams from two to 11 miles west of Houseville near the former railroad logging route in the interior of the region. Here at about 1900 feet above sea level it was common in several dense, moist woods with abundant shrubs and herbs, typical of much of the Tug Hill Plateau. Tree cover was usually conifers (spruce, fir, hemlock) and northern hardwoods, although *Napaeozapus* also was encountered in purely deciduous woods. Associates included the various woodland small mammals and often *Zapus,* the two jumping mice frequently occurring side by side in the woods. Nearly all the *Napaeozapus* were taken under the cover of woodland trees, except for five in open situations near woods, including grassy alder marshes (3), open pebbly beach of wide stream (1), on rock in middle of small stream in a field (1).

Food habits. Forty-seven individuals collected from early May to mid-September were checked for food items. The diet in general was similar to specimens of *Zapus* examined. Seeds and other plant materials made up 77.4 percent of the food by volume in the sample, while insects comprised the remainder (22.2 percent). *Plants*—seeds (mostly unidentified), 47.7 percent of volume (37 stomachs); *Endogone,* 13.7 percent (20); unidentified fungi, 3.0 percent (4); fruit, 1.7 percent (5); miscellaneous and unidentified vegetation, 11.3 percent (19). *Insects*—Lepidoptera larvae, 11.7 percent (19); Coleoptera adults, 6.5 percent (14); Orthoptera, .4 percent (1); Diptera larvae, .2 percent (1); unidentified insects, 3.4 percent (1). Certain subterranean fungi, especially *Endogone,* are now understood to be an important food of jumping mice, red-backed mice, and probably other woodland small mammals; Whitaker (1962) reported on the importance of *Endogone* in the diet of *Napaeozopus* and some other small mammals in the region of Ithaca, New York, and presented strong evidence that this food is deliberately sought out by the animals, rather than being accidentally ingested along with other foods.

Hibernation. The earliest spring date I have for Tug Hill is May 4, 1960, when two were trapped along a small woodland stream at 1750 feet in elevation. Little information was obtained relating to the time of disappearance in fall, since little trapping was done in good *Napaeozapus* habitat in October, when some may have still been about. The latest definite record and date of capture for the species was September 18.

Remarks. At least three specimens, from different Tug Hill localities, lacked completely the white tip on the tail, usually a conspicuous mark for this species, although varying in length. Accordingly, one, a juvenile, at first glance was thought to be a *Zapus.* The tails of these individual variants otherwise appeared perfectly normal, and showed no evidence of the ends having been broken off.

Reproduction. The earliest breeding female was one on May 26, which, judging from the placental scars and evidence of nursing, had already given birth to 4 young. Five others, with placental scars and nursing, taken from May 30 to July 6, probably indicated first litters of the season. Two females on July 12 and July 14 were already carrying second litters since they carried embryos and at the same time were still nursing a previous litter. Second litters were probably indicated also by other females with embryos or placental scars, in late July and August. Ten embryo and placental scar counts average 5.0 (range 3-7); two females in July carried 7 embryos each (size about 3 mm. and 9 mm.), a rather large number for this species since the reported number of young per litter is up to 6 (Palmer, 1954, and others).

Measurements. Twenty adult males (without or with very little hibernation fat) average: 21.9 grams (18.6-25.9); total length, 232.5 mm. (216-249); tail, 142.5 mm. (125-156); hind foot, 31.0 mm. (30-33). Sixteen adult females, nonpregnant or with tiny embryos and without hibernation fat average: weight 22.3 grams (17.2-27.0); total length, 235.4 mm. (214-244); tail, 144.6 mm. (135-157); hind foot, 30.3 mm. (29-31).

PORCUPINE

Erethizon dorsatum dorsatum (Linnaeus)

Porcupines were exceedingly numerous in the Tug Hill forest of western Lewis County and parts of adjoining counties. In one June, 1960, evening drive of six miles on the lumber route across the center of the forest west of Houseville (altitude 1800 to 1950 feet), we saw seven porcupines ambling along the trail. Elsewhere, porcupine dens containing large accumulations of droppings were found at ground level in the base of dead hollow trees, often sugar maples. Porcupines frequently sprang traps set for squirrels, especially when baited with apples.

The abundance of porcupines brought about the introduction of a bounty system in Lewis County beginning in January, 1964. A total of 6960 porcupines were bountied in 1964, including all 18 towns of the county. The Black River divides the county into two areas of approximately equal size, the western, or Tug Hill side, and the eastern, or Adirondack side; slightly more of the eastern side is in forest. Of the total number of porcupines, however, 4714, or over twice as many, were from the Tug Hill side, with 2246 bountied from the Adirondack area. Of the latter, most by far were from the northernmost towns of Diana and Croghan, with relatively few from the forests directly east across the river from Tug Hill. Considering the area west of the Black River alone (12 towns), the vast majority, or 4130 of the 4714 from this side came from the five interior, most heavily forested towns of Highmarket (523), Lewis (720), Martinsburg (941), Montague (819), and Osceola (1127). The other seven, more peripheral, towns of the plateau section, comprising more open land and lower slope areas, produced from 18 to 153 porcupines each.

The five leading plateau townships, in area comprising less than one-third of the county, thus yielded about 60 percent of the total kill and 88 percent of the take west of the Black River. All this merely attests to the great abundance of porcupines in the Tug Hill woods. Allowance must be made, of course, for the probability that an unknown number were taken outside of the county limits and brought in to collect the one dollar payment per animal. One likely reason for the greater abundance of porcupines in the Tug Hill sector than on the Adirondack side is the relatively small, although increasing number of fishers, which prey on porcupines. In contrast, fishers are common throughout the Adirondack section of the county, although porcupines remain numerous in some parts of that area too.

COYOTE

Canis latrans Say

Coyotes invaded northern New York, presumably from Canada, early in this century and they have continued to spread and increase so that today all of the Tug Hill region, as well as the Adirondacks, lies within their range. Judging from signs observed and reports received, coyotes were fairly numerous in the winter of 1959-60 along the northern edge of the main forested section, in the townships of Montague and Martinsburg, where I spent time afield trapping small mammals. In this section, their tracks indicated they used certain frozen, snow-covered streams as routes of travel. Based on validated bounty records and field observations by Conservation Department personnel, coyotes occur in all the townships of the plateau, and information based on the bounty records and complaints received indicates the population in this area has remained rather stable for the past 15 years (J. E. Wilson, *pers. comm.*).

RED FOX

Vulpes fulva fulva (Desmarest)

The red fox is common on the Tug Hill Plateau, and we frequently saw them along the back roads and in the abandoned fields on top of the plateau. This species is perhaps most numerous about the old fields, meadows, and bushy habitats along the fringe of the deeper woods. In these areas, in the deep snow of winter, the tracks of red fox and varying hare were just about everywhere. The varying hare is undoubtedly an important staple in the diet of the red fox in this area, as well as of other predators such as the bobcat and coyote. In several years of rabies control work by State fox trappers between 1949 and 1962, approximately 5000 red foxes were trapped on Tug Hill as a whole, that is, in the area from the Delta Reservoir north to Watertown, and from the Black River west to the Town of Boylston in Oswego County. Many were taken in every township, indicating that the red fox is common and well spread over the area.

GRAY FOX

Urocyon cinereoargenteus (Schreber)

During recent decades the gray fox has increased in numbers and expanded its range in northern New York (see Hamilton, 1943; Seagears, 1944); this is part of a general northward movement of the species, with the evidence for some regions indicating a reinvasion of territory held a few centuries earlier. While the range of the gray fox extends to the northern border of the State, conditions on the upper part of Tug Hill are less suited to it than are the nearby lowlands, and it resembles the opossum and cottontail in its local distribution at the present time. Conservation Department records of State fox trappers who covered this area between 1949 and 1962 seem to indicate this. No gray foxes were recorded by these trappers from any of the six higher Lewis County townships west of the escarpment where most of the land lies above 1300 feet (Highmarket, Harrisburg, Lewis, Montague, Osceola, and Pickney), and where a total of 1026 red foxes were trapped; 431 of the reds were taken in Highmarket and Montague, the only towns situated entirely above the 1500 foot contour.

Several gray foxes were trapped along the eastern edge of the area in Leyden, Turin, West Turin, and Lowville, townships which extend from the Black River Valley up onto the eastern edge of the plateau. As these towns overlap the two sections, it is not possible from the data available to state whether or not they were taken on Tug Hill; quite likely they came from the valley or lower slopes. On the western side of Tug Hill there is one record each, both 1951, for Redfield in Oswego County, and Worth in Jefferson County. These towns border the high plateau section of western Lewis County, and the highest record for the control trappers may be the one from Worth, where elevations range from 1100 to 1700 feet.

For Tug Hill as a whole, highest populations of gray foxes apparently occur on the southern slopes in northern Oneida County, which was trapped between 1949 and 1954. Here 35 grays were taken by the fox trappers in Ava, Annsville, Florence, Lee, and Western, between the Delta Reservoir and the northern boundary of the county (837 red foxes were trapped in this same area). The majority of the gray foxes came from Annsville; in this town all of the land is below 1500 feet.

In summary, then, the gray fox is found on all sides of Tug Hill and at present seems to be thinly spread over the lower slopes, being most common along the southern margin of the area in Oneida County, but apparently has not established itself in any numbers on the upper level.

BLACK BEAR

Ursus americanus americanus Pallas

At the present time, bears are scarce on Tug Hill according to all sources of information, in contrast with most of the Adirondack region where they are numerous. Few kills of bears are now made west of the Black River according to Conservation Department records (see Anon., 1956, and Free, 1960). Sight observations are occasionally reported: one was sighted in 1952 on the western slope in the Littlejohn Game Management area, Town of Boylston, while another occurred in 1962 at Michigan Mills as reported by Conservation Officer Regetz of Constableville (J. E. Wilson, *pers. comm.*). The bears that occur in this region probably are transients that have wandered across from the Adirondacks, although the wilderness area in the interior of the plateau may possibly support a small population.

Formerly, this area was well known for its black bears. In fact, Merriam (1882), under his account of this species in the Adirondacks, apparently makes his only reference to the Tug Hill forest in his publication when he states (p. 96) that: "In Lewis County, about twenty miles west of the western border of the wilderness, is an uninhabited tract of evergreen forest, covering portions of the towns of Highmarket, Osceola, Montague, and Pinckney. In this forest dwell many bears, and in the fall they often cross over the intervening valley, a fertile farming country, and enter the Adirondacks. At such times they occasionally pass through our own grounds, at Locust Grove, in the town of Leyden; and during one October, about five years ago, no less than nine bears were killed within six miles from my residence."

RACCOON

Procyon lotor lotor (Linnaeus)

Raccoons are common and may be encountered anywhere on the Tug Hill Plateau. Their tracks are numerous along the many quiet waterways, and we saw signs of their feeding on crayfish and frogs, which abound there. They also roam the woods, fields, bogs, swamps, and ravines. Raccoon activity was noted in every month on the uppermost level of the plateau, except during their period of dormancy during December, January, and February. State fox trappers in the 1950's captured raccoons in all townships of the plateau region.

FISHER

Martes pennanti pennanti (Erxleben)

The fisher, although still uncommon, has returned to the Tug Hill Plateau after a long absence. This handsome member of the weasel family is occasional in the Black River Valley and is slowly increasing on the plateau, but is much more numerous on the eastern or Adirondack side of the Black River. This is illustrated by Hamilton's (1955) map of trappers' take of fisher in New York in 1950 and 1951, which for Lewis County shows nearly all of the records concentrated in the eastern half of the county across the Black River Valley barrier, which runs up the middle of the county. A few of the records, however, are grouped in the Tug Hill area. State fox trappers caught several fishers between 1951 and 1962 on the upper level of the plateau in western Lewis County, including two in Montague, one in Highmarket.

John E. Wilson (*pers. comm.*) contributed the following recent information for Tug Hill: Conservation Officer Don McIntosh reported tagging a fisher taken in 1963 at Rodman, Jefferson County, while Conservation Officer John Van Zandt reported the same for a fisher taken in the Town of Montague, Lewis County, in 1964. The officers with which Wilson recently discussed the occurrence of fisher were all of the opinion that the fisher is increasing in numbers in all the forested townships of the Tug Hill area.

The spread of the fisher across the farmlands and woodlots of the Black River Valley and into the Tug Hill sector is a result of its notable increase and expansion from its retreat in the Adirondack heartland beginning in the 1940's. Porcupines have been known to decline sharply in numbers following an increase in fishers, and there is evidence of frequent predation also by fishers on raccoons in the Adirondacks (see Hamilton, 1955). However, porcupines and raccoons were numerous all over Tug Hill during the time of this study. The only fisher I observed afield was one seen at midday in June 1960, just outside of this region in Adirondack lowlands north of the Lewis County line. But if the indicated slow but steady increase of the fisher continues, this should eventually result in a decline on Tug Hill of the excessively numerous porcupine.

SHORT-TAILED WEASEL OR ERMINE

Mustela erminea cicognanii Bonaparte

Specimens taken. 19

Distribution and habitat. Both species of weasel were common on top of the plateau as well as at lower elevations in the region, although all of the specimens of *erminea* were collected above 1650 feet. Fifteen fall and spring specimens of *erminea* were taken in fields and shrubby places (*Microtus* habitat) on abandoned farmland on the hill, especially along old stone walls, culverts for small streams, and around old buildings. In the deep snow of winter a few were taken where fresh tracks were noted, in woods and at an old collapsed barn. In winter, though, the tracks of these small weasels were often noted in many habitats: in various woods, along streams, along the edges of fields and meadows, etc. The animals often travelled beneath as well as above the surface of the snow, often emerging or entering at natural cavities in the snow at the base of trees and shrubs, and at stumps and logs. Occasionally, fresh tracks showed where one of these active little carnivores had crossed my snowshoe trail within an hour or two after I had passed.

Food habits. Ten stomachs were empty, while nine contained the remains of small mammals: meadow mouse (5), short-tailed shrew (1), red squirrel (1), and unidentified (2).

Reproduction. A female taken April 25 had 7 embryos measuring 13 mm. crown to rump. Two adult males taken April 23 and May 3 had enlarged testes measuring 12 to 13 mm. in length; half this length or less in fall and winter specimens.

Pelage. Of 11 from the plateau in the second half of October all were still in brown dress, with only two showing some incoming white hairs, chiefly on the tail. Winter weasels were white, while three in late April and early May had already changed back to brown, except for lingering areas of white on the tail, and in one individual, all along the sides also.

Measurements. Nine adult and subadult males (Oct. 15 to May 3) average: weight, 109.6 grams (77.3-123.3); total length, 285.4 mm. (257-303); tail, 75.8 mm. (64-85); hind foot, 37.4 mm. (34-42). A male on October 24 was much smaller than the others, being the smallest in each of the above measurements (next smallest: 100.9 grams, 279 mm., 72 mm., 36 mm.), and it closely resembled the females in size, although examination of it in the flesh showed more massive head and limbs; the skull seemed to indicate this male was in the same general age class as four other October males, a subadult born the preceding spring, but the others were full grown. Eight adult and subadult nonpregnant females (Oct. 15 to Feb. 10) average: weight, 67.6 grams (60.6-76.6); total length, 243.6 mm. (230-254); tail, 61.0 mm. (54-65); hind foot, 30.1 mm. (29-31).

LONG-TAILED WEASEL

Mustela frenata noveboracensis (Emmons)

Specimens taken. 7

Distribution and habitat. On Tug Hill this species lives in many of the same habitats with the smaller ermine. Individuals of both species occasionally investigate the same patch of meadow or stretch of old stone wall in a day's hunting. *Mustela frenata* was taken from the Black River Valley at 750 feet elevation up to the top of the plateau at 1900 feet. Four were trapped in the fall on abandoned agricultural land on the hill (at a stone wall, a culvert, and an old barn), along with several *erminea* in the same fields and meadows. In the winter, tracks of this larger species were seen in many localities—in the woods, along the side of streams and ponds, and skirting fields and meadows. In their rounds, these animals examined holes and cavities in the snow, logs, stumps, and trees, old buildings, etc., and sometimes tunneled through the snow in the manner of *erminea.*

Although the short-tailed weasel probably outnumbers this species, at least on the higher slopes of the plateau, the small rat traps used in this survey favored getting the smaller *erminea;* several female *frenata,* but no weasels of the largest size class, the males of this species, were caught with these traps. A steel trap was resorted to in order to collect a male in winter, in a patch of thick woods where it repeatedly sprang and robbed the smaller rat traps and also carried off several small traps which had caught mice and shrews.

Weasels were observed in the wild on several occasions. Late in April near Rector (elev. 1800 feet) weasels of this species, probably two individuals, were observed going in and out of two entrances to an old overgrown woodchuck burrow in a patch of coniferous woods near a meadow. April being the month in which litters are usually brought forth, it is likely that these weasels were a pair with young in a nest down in the burrow.

Pelage. All weasels seen and collected on Tug Hill in winter were white, including one of this species still entirely white, without signs of spring molt, on March 25. A male *frenata* observed at close range in the field on April 29 was brown except for white hairs remaining on the tail and scattered along sides of the body.

Measurements. Two adult males (winter) average: weight, 232.4 grams (227.8-237.0) ; total length, 411.5 mm. (403-420) ; tail, 143.0 mm. (138-148) ; hind foot, 48.0 mm. (48-48). Four females (October) average: weight 125.2 grams (108.6-137.7); total length, 333.8 mm. (311-346); tail, 110.3 mm. (100-119); hind foot, 37.8 mm. (36-40).

MINK
Mustela vison Schreber

Common on Tug Hill, minks range up and down all the streams of the plateau, sharing these waterways with otters, raccoons, muskrats, beavers, and water shrews. Tracks were noted at all seasons; their winter trails often showed where these active animals traveled through the woods, coasted otter-like for short distances down slopes and stream banks, ran along the snow-covered frozen waterways, or entered the water through the occasional cracks and holes in the ice.

STRIPED SKUNK
Mephitis mephitis nigra (Peale and Palisot de Beauvois)

The skunk did not seem to be especially abundant on Tug Hill during the study but it was observed at all elevations, in the more open agricultural and woodlot sections on the high eastern edge of the plateau, as well as in the lower valley areas nearby. We did not encounter this species in the densely forested central region of Tug Hill, where it is probably not as common as in the more varied surrounding countryside. But it may be that the skunk and its "signs" are less readily observed in such a heavily wooded region. State fox trappers in the period 1949 to 1962 caught hundreds of skunks in the Tug Hill region as a whole, including many from the high townships of Highmarket, Montague, etc. Also, in 1952, skunks were taken in varying hare traps in the Lilypad section in the interior of the Tug Hill forest traversed by the route of the Glenfield and Western Railroad (J. E. Wilson, *pers. comm.*).

RIVER OTTER

Lutra canadensis canadensis (Schreber)

Otters are of regular occurrence in the Lewis County, Jefferson County, and Oswego County sections of the Tug Hill Plateau, and they undoubtedly find favorable habitat along the many sizable streams in the wilder parts of this area. The species is well known to the few local trappers, some of whom have occasionally taken several otters in a season in recent years, and to other interested people of the region. John E. Wilson informs me that the otter is common on Tug Hill, including the Town of Worth in Jefferson County. I noted tracks and other signs of otters in winter in the Town of Montague, Lewis County.

BOBCAT

Lynx rufus rufus (Schreber)

Bobcats are common on the plateau at the present time. Although we did not see any alive, I studied their tracks in several areas, especially in the mud of the old railroad logging route through the high Tug Hill woods and swamps west of Houseville. John E. Wilson tells me that the bobcat is common on Tug Hill, and several local residents and outdoorsmen spoke of occasionally seeing the animals. The Adirondack region is the primary range of the bobcat in New York, but Lewis County bounty records as well as other sources point to the interior of Tug Hill as a local center of abundance. Of the 157 bobcat bounties reported for 1963 and 1964, 98 of the cats, or 62 percent of the county total, were listed from the five high, heavily wooded Tug Hill townships of Highmarket, Lewis, Martinsburg, Montague, and Osceola.

WHITE-TAILED DEER

Odocoileus virginianus borealis (Miller)

Little information was obtained regarding the current status of deer on Tug Hill. Based on casual observations, deer are quite numerous locally, but the plateau as a whole probably supports a lower density of deer than sections of the Adirondacks and some other hilly parts of the State. The extraordinary depth of the snow usual in winter on the upper heights probably is important in reducing the population there. Along the logging route across the interior of the densely wooded upper level east and west of Page, deer were present but not abundant in summer (1960) to judge from the only occasional sightings of deer or their tracks, although a few deer with fawns were noted at scattered points in this section. Hunting of deer seemed to me to be relatively light on the upper part of the plateau and in the forested interior. During the winter, deer are restricted by the deep snows of Tug Hill to a few yarding areas; for several months in the winter of 1959-60 I saw no signs of deer over extensive areas outside of these local areas of concentration or "yards". With the arrival of ameliorating conditions in spring, the deer spread out more on the plateau. Such movements must involve trips of several miles for many of the deer.

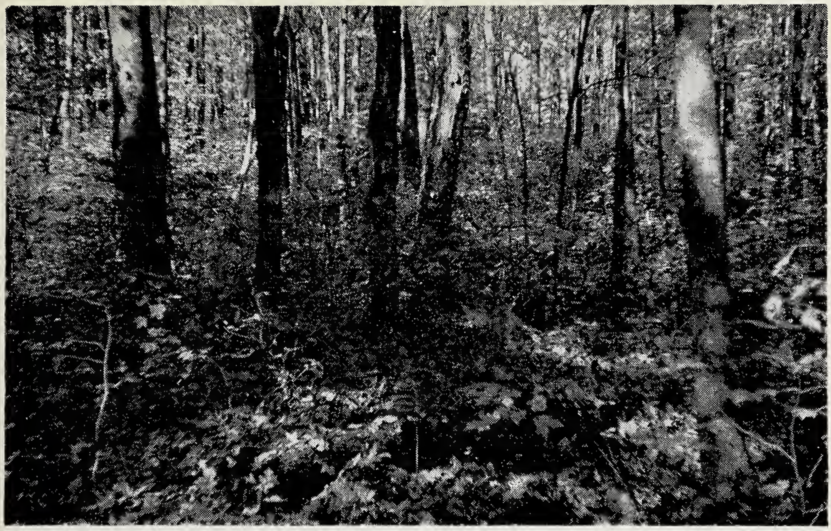


FIGURE 1. Beech-maple-yellow birch woods 6 miles southwest of Lowville, elevation 1900 feet, October. *Sorex cinereus, S. fumeus, Blarina, Parascalops, Tamias, Tamiasciurus, Peromyscus maniculatus, Microtus, Clethrionomys, Pitymys,* and *Napaeozapus* collected here.

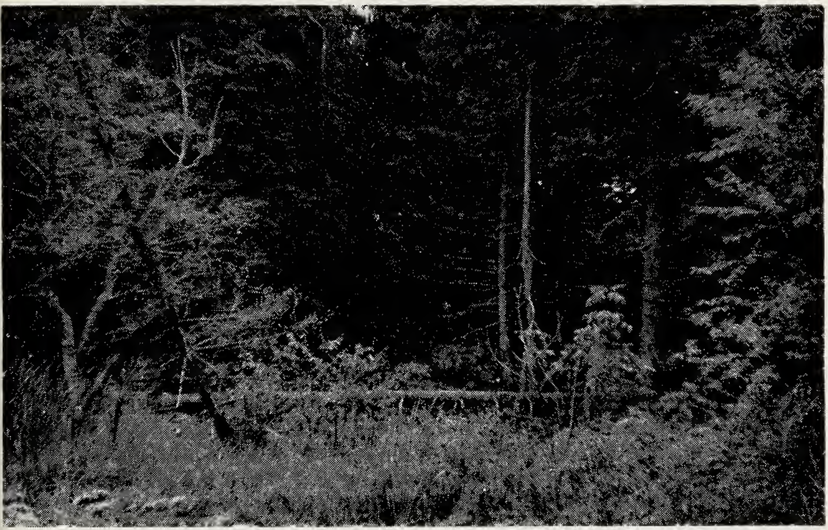


FIGURE 2. Dense woods, mostly red spruce, balsam fir, and red maple, in moist area near Sears Pond, elevation 1750 feet, August. *Sorex cinereus, S. fumeus, Blarina, Tamias, Peromyscus maniculatus. Clethrionomys, Microtus, and Napaeozapus* collected. *Condylura,* varying hare, porcupine present.

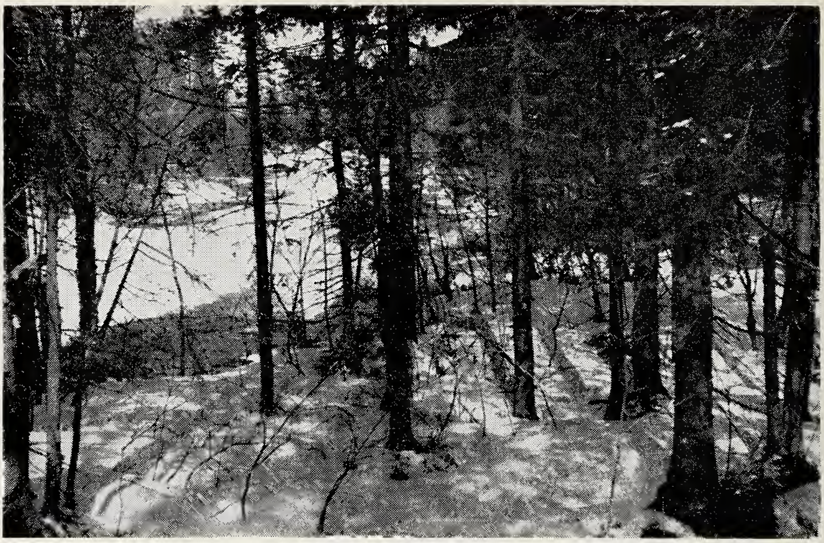


FIGURE 3. Woods of red spruce, fir, hemlock, and yellow birch near Sears Pond, elevation 1740 feet, April. *Sorex cinereus, S. fumeus, Blarina, Lepus americanus, Clethrionomys, Microtus, Peromyscus maniculatus, Napaeozapus, Mustela frenata,* and *M. erminea* collected.

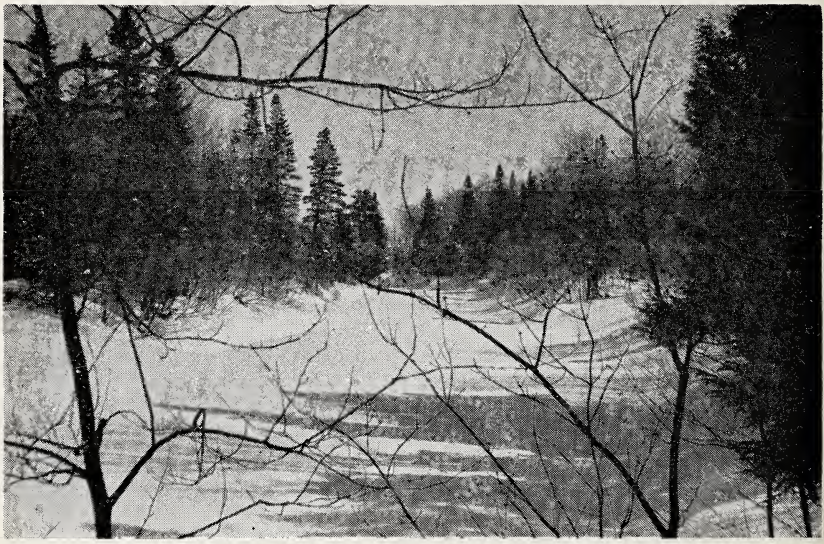


FIGURE 4. Edick Creek near Sears Pond, elevation 1740 feet, March. Varying hare, muskrat, porcupine, coyote, red fox, long-tailed and short-tailed weasels, mink, and otter seen or tracks noted in deep snow here.

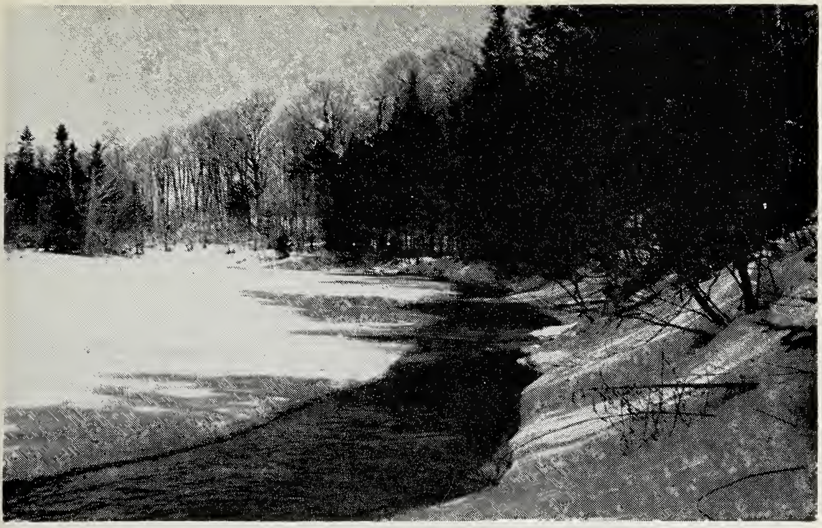


FIGURE 5. Edick Creek near Sears Pond, elevation 1740 feet, April. *Sorex cinereus, S. fumeus, S. palustris* (4), *Blarina, Peromyscus maniculatus, P. leucopus, Clethrionomys,* and *Microtus* trapped along bank on right in late fall and in April.

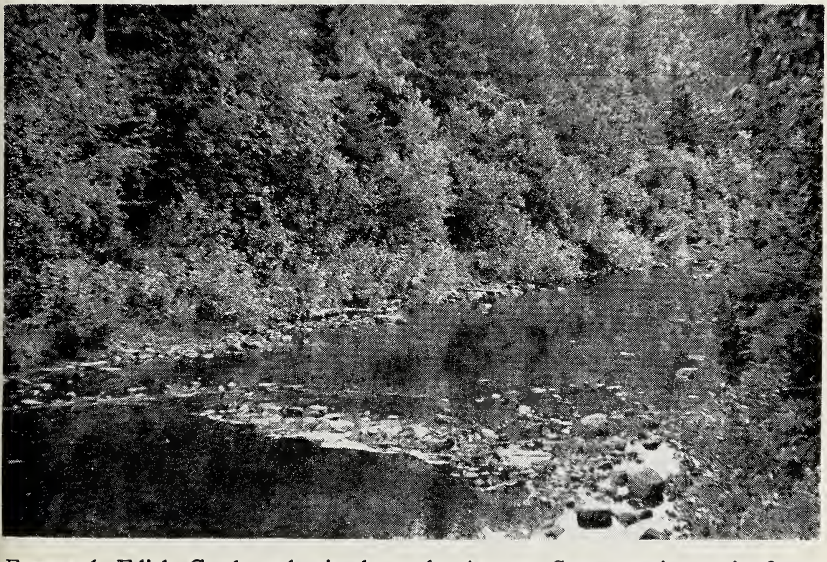


FIGURE 6. Edick Creek and mixed woods, August. Same species as in figure 5, but farther upstream. *Myotis lucifugus* in summer.

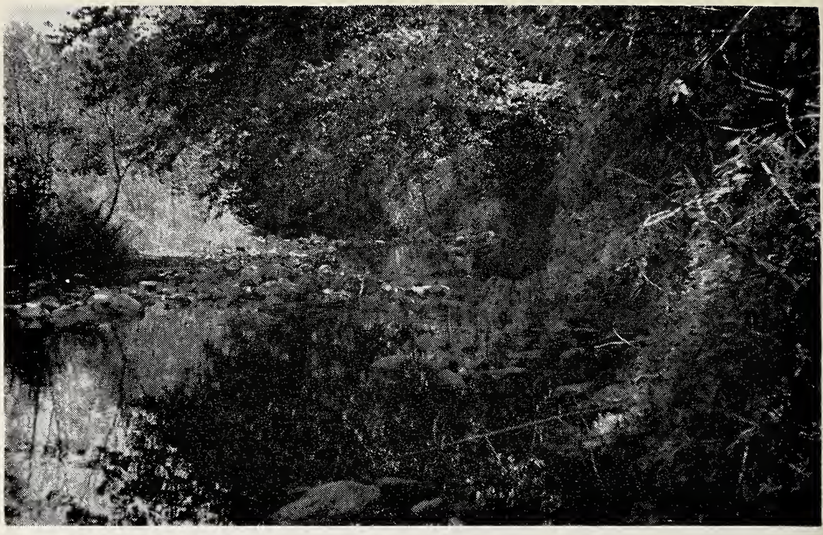


FIGURE 7. Sevenmile Creek, 10 miles west of Houseville, elevation 1820 feet, July. *Sorex fumeus, S. palustris* (4), *Peromyscus maniculatus, Clethrionomys, Microtus, Zapus,* and *Napaeozapus* trapped under mostly deciduous trees along bank on right. Also tracks of muskrat, raccoon, and mink.

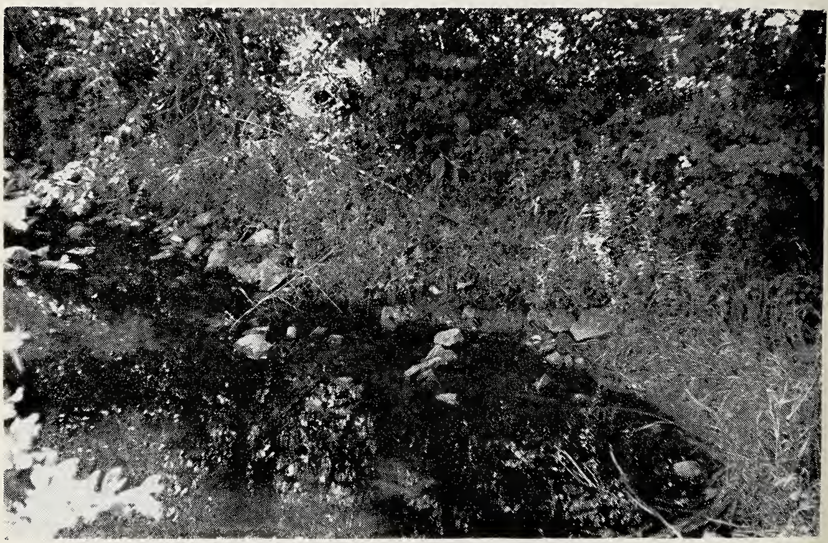


FIGURE 8. Sevenmile Creek. Close-up of small section of shoreline; water shrew trapped left of center under stick protruding out over water.

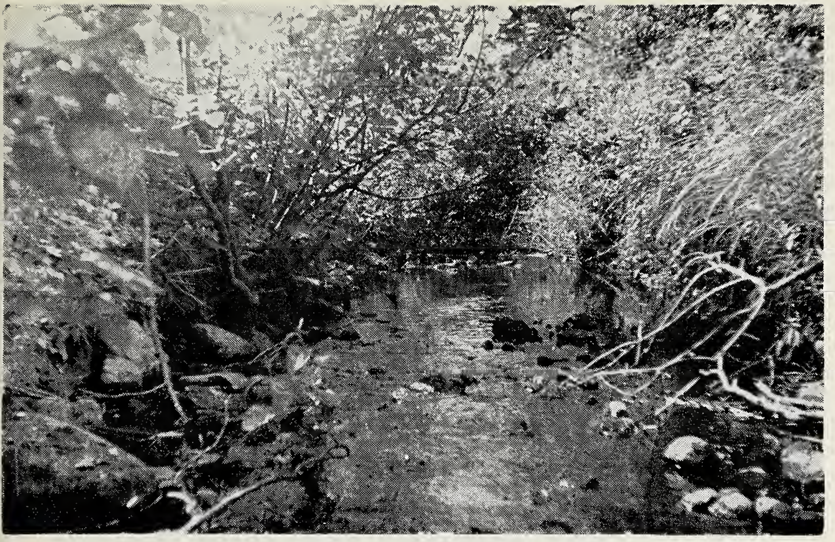


FIGURE 9. Small tributary of E. Branch Fish Creek, 9 miles west of Houseville, elevation 1820 feet, July. Five *Sorex palustris* trapped under alders on left in area shown. Also *Microtus, Zapus,* and *Napaeozapus* present, and signs of muskrat and beaver.

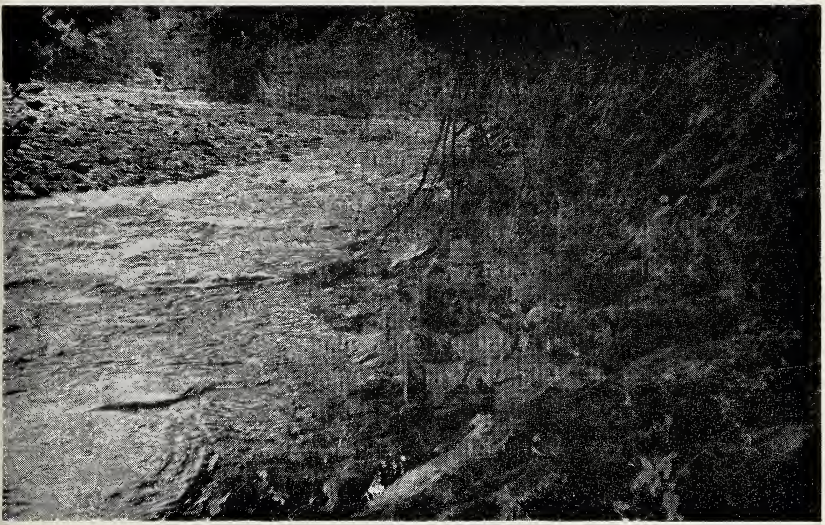


FIGURE 10. E. Branch Fish Creek, 6 miles west of West Leyden, elevation 1300 feet, July. *Sorex fumeus, Sorex palustris, Peromyscus maniculatus,* and *Napaeozapus.* Site of capture of water shrew among limestone rocks pointed out.

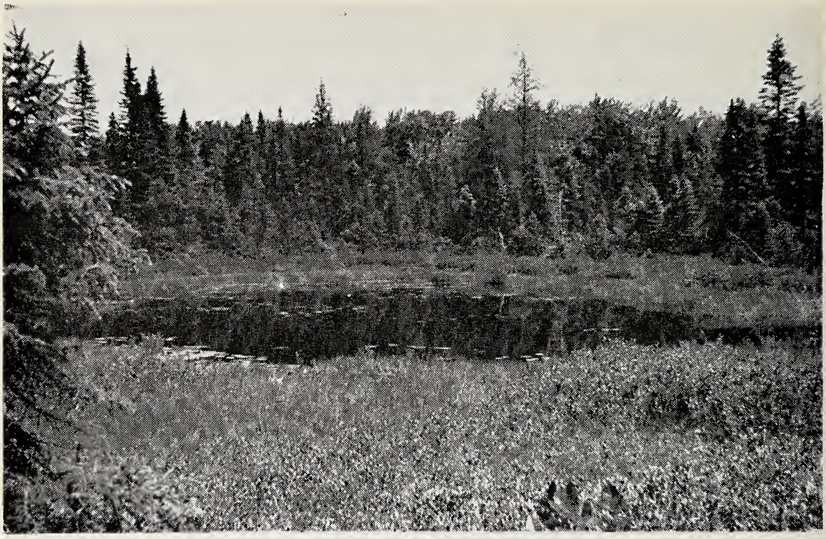


FIGURE 11. Bog with pond 10½ miles west of Houseville, elevation 1830 feet, July. Sedge, shrub (leatherleaf, etc.), and spruce-tamarack zones around pond. *Sorex cinereus* and *Microtus* common in sedge and shrubs; also 2 *Sorex palustris* collected in this bog. Tracks of raccoon, deer.

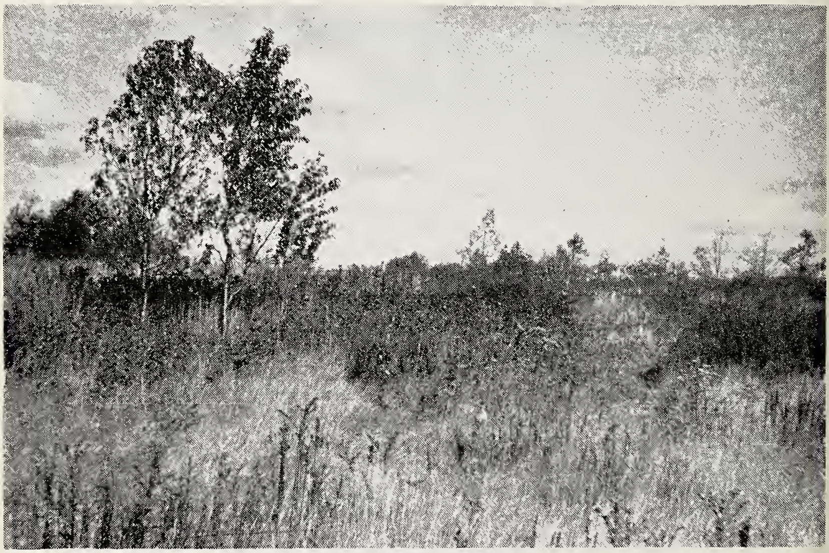


FIGURE 12. Old overgrown fields with damp spots, 6 miles southwest of Lowville, elevation 1950 feet, October. *Sorex cinereus, Blarina, Condylura, Microtus* collected.

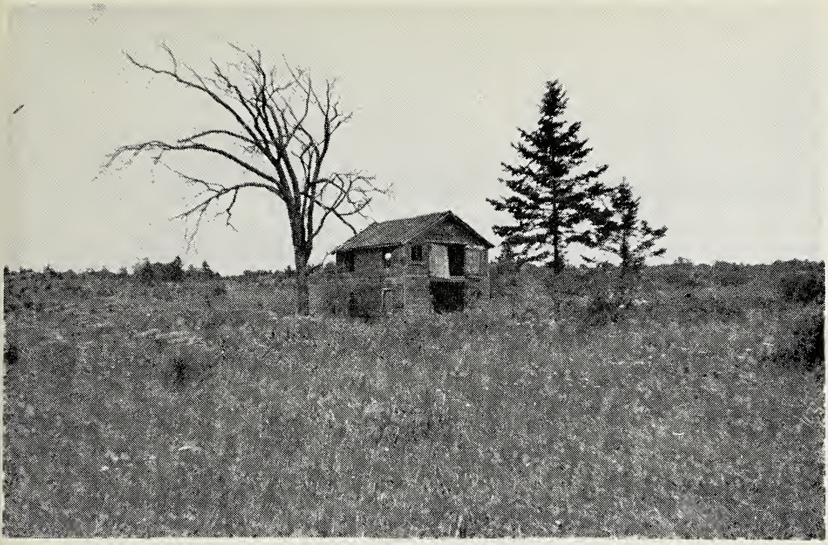


FIGURE 13. Abandoned farm near Rector, elevation 1700 feet, August. *Blarina, Microtus,* woodchuck, both species of weasel, and red fox common.

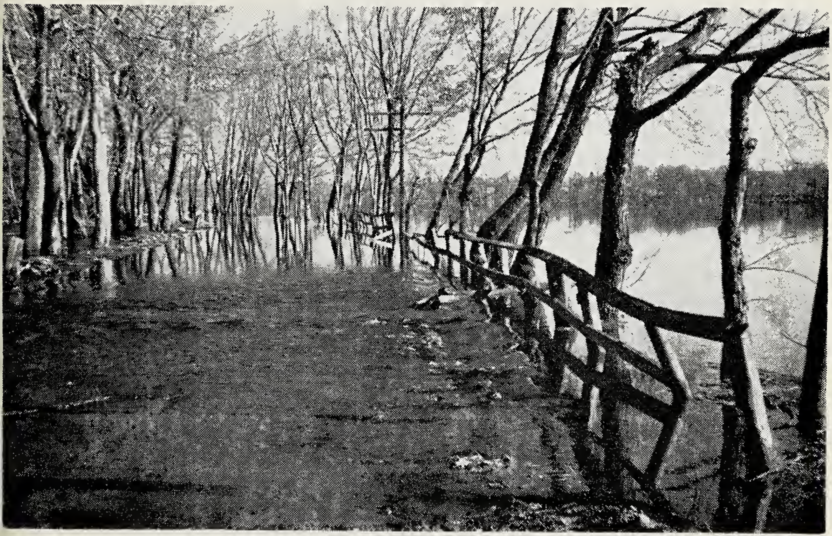


FIGURE 14. Flooded road (left) and meadow (right) 2 miles southeast of Lowville, elevation 730 feet, November 8, 1959. Overflowing Black River out of view to left and in background. Mammals were flooded out of the meadow to the road by the rising water the previous evening; meadow mice climbed the willow trees by fence (see text).

Siphonaptera Collected on Tug Hill, Lewis County, New York

by **Allen H. Benton,** Professor of Biology
State University College at Fredonia, New York

DURING THE COLLECTING OPERATIONS in Lewis County, 118 specimens of Siphonaptera were collected and turned over to me for identification. In this material were 13 species of fleas, taken from 12 different species of mammalian hosts. The annotated list follows:

Family Hystrichopsyllidae

Hystrichopsylla tahavuana Jordan. 1 male.
Host: *Microtus pennsylvanicus*
Commonly a mole flea; the meadow vole is an accidental host.

Epitedia wenmanni wenmanni (Rothschild). 3 females.
Hosts: *Blarina brevicauda*—1
Peromyscus maniculatus—1
Mustela erminea—1
Most frequently on deermice, but not particularly host-specific.

Tamiophila grandis (Rothschild). 2 females.
Host: *Tamias striatus*
One of our two common chipmunk fleas.

Corrodopsylla curvata curvata (Rothschild). 2 males, 4 females.
Host: *Sorex palustris*
Fleas are seldom taken from the water shrew, or indeed from any aquatic mammal. This flea is most often found on shrews of the genus *Sorex,* but I do not know of any previous records from *Sorex palustris* in the east. Conaway (1952) found five fleas on 119 western water shrews (*S. p. navigator*), one of which was of this species.

Ctenophthalmus pseudagyrtes pseudagyrtes Baker. 12 males, 12 females.

Hosts: *Pitymys pinetorum*—5
Condylura cristata—6
Microtus pennsylvanicus—7
Blarina brevicauda—2
Mustela erminea—2
Tamias striatus—1
Tamiasciurus hudsonicus—1

This is a very abundant flea, and may be found on any mammal.

Doratopsylla blarinae C. Fox. 9 males, 12 females.

Hosts: *Blarina brevicauda*—19
Microtus pennsylvanicus—1
Sorex fumeus—1

An exceedingly specific parasite of *Blarina,* this species is only rarely found as an accidental parasite of other small mammals.

Nearctopsylla genalis genalis (Baker). 2 females.

Hosts: *Condylura cristata*—1
Mustela erminea—1

Generally a flea of shrews and moles. The specimen from a weasel is no doubt due to predation or accidental contact.

Family Ceratophyllidae

Megabothris acerbus (Jordan). 4 males, 3 females.

Host: *Tamias striatus*

The most common of chipmunk fleas, found throughout the State.

Megabothris asio asio (Baker). 6 females.

Hosts: *Microtus pennsylvanicus*—5
Mustela erminea—1

The meadow vole is the typical host of this flea. It has been found to be most easily secured from nests.

Megabothris quirini (Rothschild). 2 females.

Hosts: *Microtus pennsylvanicus*—1
Napaeozapus insignis—1

Most commonly found on *Clethrionomys gapperi* and *Microtus chrotorrhinus*. Less frequently, it is taken from the above two, but neither of them is of primary importance as a host.

Monopsyllus vision (Baker). 7 males, 8 females.

Hosts: *Tamiasciurus hudsonicus*—13
Tamias striatus—1
Mustela frenata—1

As the above data imply, this is a red squirrel flea, common throughout the range of its host in New York.

Orchopeas caedens durus (Jordan). 6 males, 19 females.

Hosts: *Mustela frenata*—3
Tamiasciurus hudsonicus—22

Another red squirrel flea, but occurring only in the Adirondack mountains and the Tug Hill Plateau in New York, so far as present collections indicate.

Orchopeas leucopus (Baker). 3 males, 1 female.

Host: *Peromyscus maniculatus*

The common parasite of both species of *Peromyscus* in the northeast.

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507.73

TABLE 3

CONODONT SPECIES	NUMBER OF SPECIMENS
Acodus inornatus	88
A. numaltipes	7
A. similaris	4
A. aff. *A. unicostatus*	22
Acontiodus falcatus?	1
A.? *curvus*	8
Ambalodus elegans	34
A. pulcher	17
A. triangularis	551
Amorphognathus ordovicica	262
A. tvaerensis	2
Belodina diminutiva	17
B. dispansa	14
B. compressa	814
B. inclinata	17
B. ornata	8
Bryantodina abrupta	44
Coelocerodontus tetragonius	12
C. trigonius	69
Cordylodus delicatus	514
C. flexuosus	310
C. n. sp.	9
Dichognathus brevis	11,122
D. typica	
Distacodus falcatus	51
D. procerus	57
D.? *trigonius*	13
Drepanodus amoenus	*D.* spp. 3,233
D. planus	
D. cf. *D. arcuatus*	
D. cf. *D. homocurvatus*	
D. suberectus	187
Eobelodina fornicala	168
Falodus prodentatus	420
Goniodontus superbus	10
Holodontus superbus	17
Icriodella superba	127
Ligonodina tortilis	31
Oistodus abundans	6,799
O. inclinatus	530
O. pseudoabundans	123
O. venustus	66
Ozarkodina cf. *O. tenuis*	538
Paltodus dissimilaris	4
Panderodus arcuatus	*P.* spp 6,517
P. compressus	
P. feulneri	
P. striatus	
Periodon aculeatus	319
Phragmodus undatus	19,162
P. cognitus?	11
Polyplacognathus bilobata	369
P. ramosa	886
Prioniodina macrodentata	119
P. pulcherrima	187
P. robusta	61
Rhipidognathus paucidentata	25
Rhynchognathodus divaricatus	62
R. typicus	32
Rosagnathus delicata	350
Sagittodontus dentatus	23
S. robustus	48
Scolopodus insculptus	41
Trichonodella barbara	35
T. exacta	104
T. flexa	120
T. recurva	50
T.? *tricurva*	20
Zygognathus deformis	210
"Fibrous" Conodonts	110

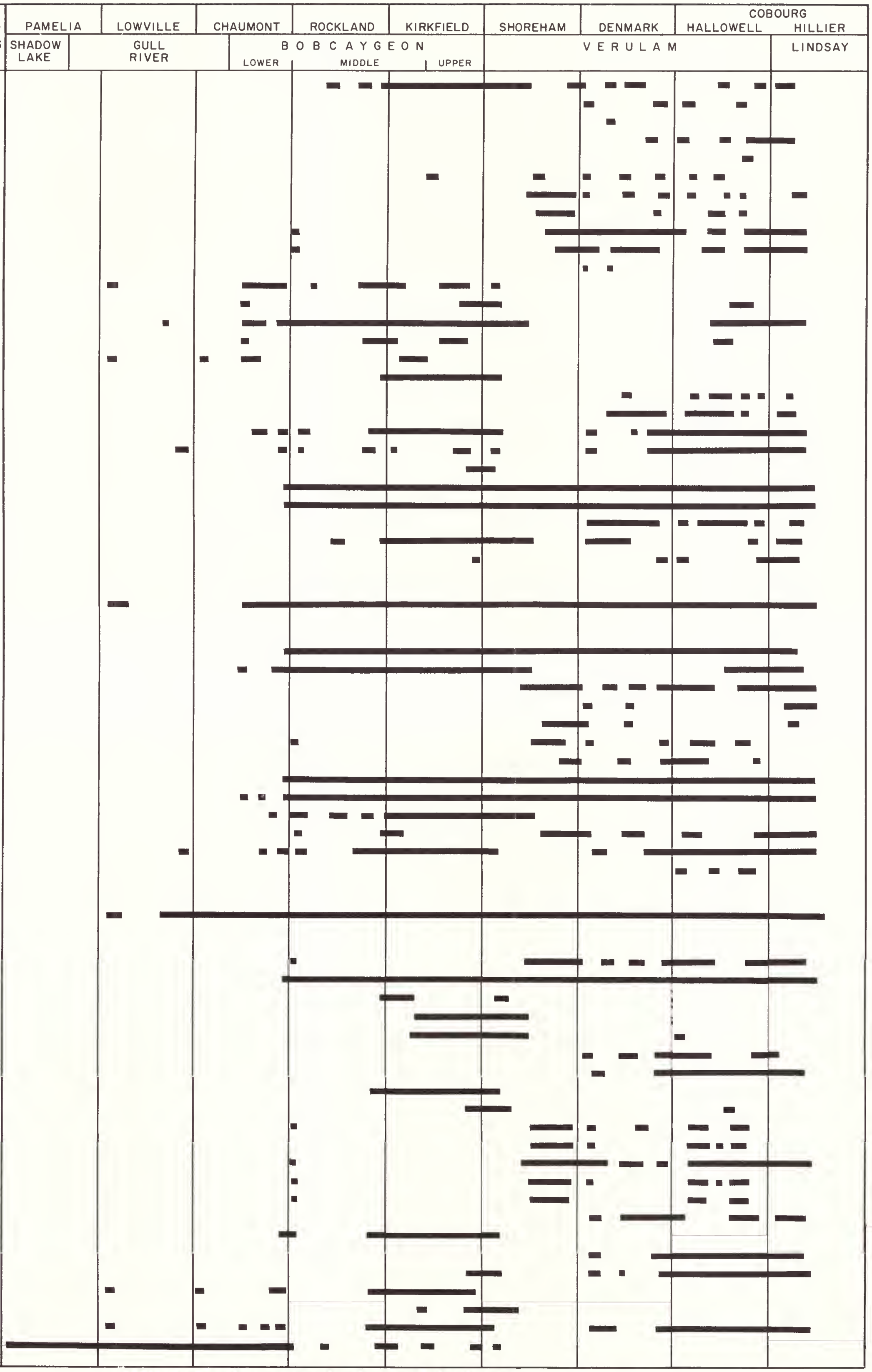


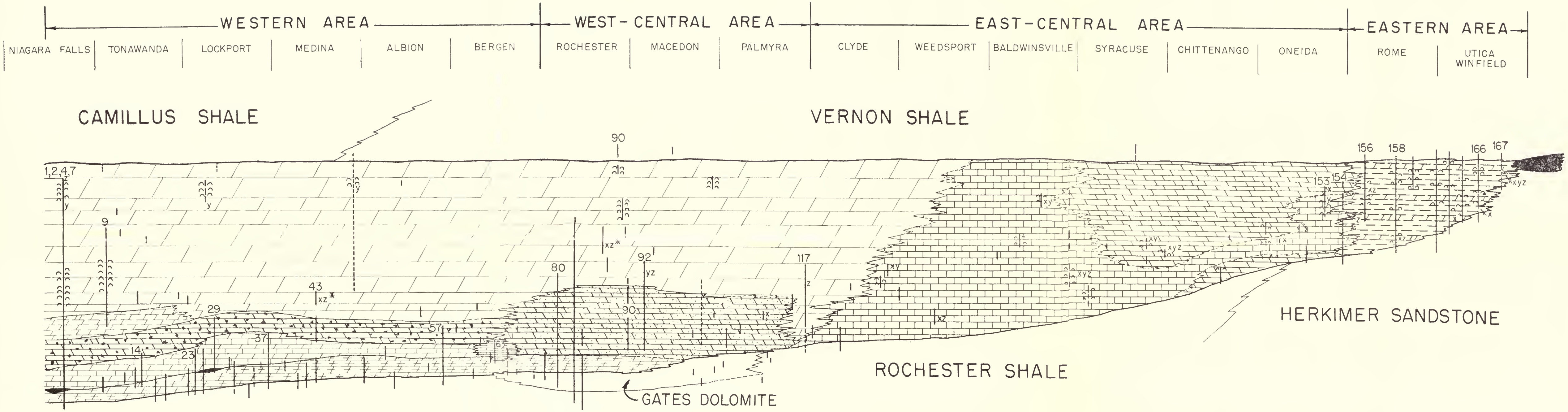
TABLE 3. Conodont species abundance and distribution.

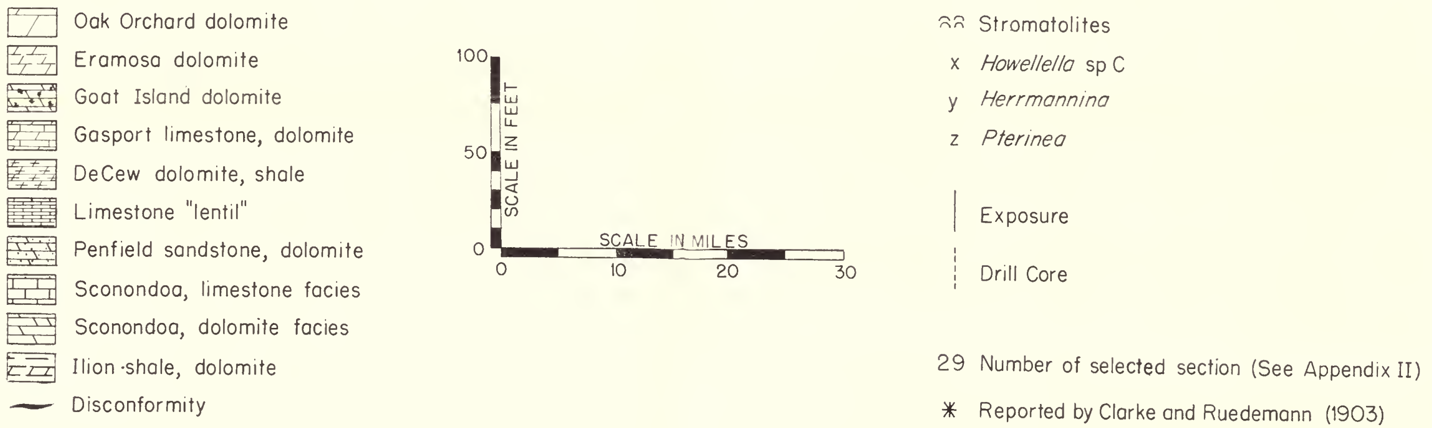
TABLE 4	INGHAM MILLS										
	LOWVILLE	ROCKLAND		KIRKFIELD							SHOREHAM
SAMPLES→	1,2,3	4	10	16	20	30	35	45	54	57	
Acodus inornatus											
Acontiodus? curvus											
Ambalodus elegans									1	1	
A. triangularis											
Belodina compressa					1	4		2			
B. diminutiva	?1					1					
B. inclinata											
Cordylodus delicatus						4	1				
C. flexuosus	2	?1				1	?1				
Dichognathus spp.					7	70	24	35	10	1	
Distacodus procerus											
Drepanodus suberectus			1			4		1	1		
D. spp.			1		5	18	3	25	17	2	
Eobelodina fornicala						1		1			
Oistodus abundans					4	90	10	30	4		
O. inclinatus			1		1	6	4	1	1	2	
O. pseudoabundans											
O. venustus											
Ozarkodina cf. *O. tenuis*	1				1	2	1				
Panderodus spp.			1		1	4		2	5		
Periodon aculeatus											
Phragmodus undatus					9	120	40	35	7	4	
Polyplacognathus bilobata								1	5	5	
P. ramosa								6	25	2	
Prioniodina robusta	?1										
Trichonodella barbara					?1		1	?1			
T. exacta											
T. recurva											
T.? tricurva											
Zygognathus deformis						2		1			
"Fibrous"	20	2			2						
Totals	25	3	4		32	327	85	141	76	17 (710)	

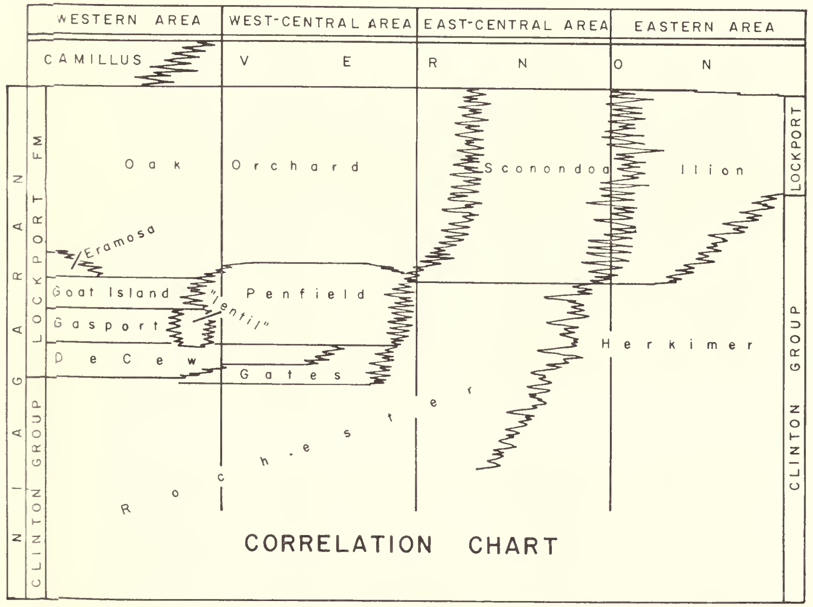
	CITY BROOK							
	KIRKFIELD					SHOREHAM		
SAMPLES→	1	10	20	30	39	40	50	60
Acodus inornatus	2						2	1
Acontiodus? curvus								
Ambalodus elegans								
A. triangularis								
Belodina compressa	15	9	2	2			5	2
B. diminutiva	1							
B. inclinata	?1							
Cordylodus delicatus			2					
C. flexuosus			1	1				
Dichognathus spp.	110	35	45	45	14		240	15
Distacodus procerus								1
Drepanodus suberectus	4						3	
D. spp.	35	7	9	6	4		16	15
Eobelodina fornicala	6	2	1	2			3	
Oistodus abundans	110	19	30	25	8		110	18
O. inclinatus	4	2					3	
O. pseudoabundans	1		1					
O. venustus	3							
Ozarkodina cf. *O. tenuis*			3	1				
Panderodus spp.	80	1	12		1		35	22
Periodon aculeatus								
Phragmodus undatus	160	50	60	45	10		450	45
Polyplacognathus bilobata		1					25	7
P. ramosa		4		4	6		35	30
Prioniodina robusta								
Trichonodella barbara								
T. exacta				?1				
T. recurva								
T.? tricurva								
Zygognathus deformis								
"Fibrous"	6							
Totals	538	130	166	132	43		927	156 (2092)

	MARTINSBURG, ROARING BROOK																						TOTAL
	ROCKLAND							KIRKFIELD											SHOREHAM				
SAMPLES→	3	5	10	17	26	35	41	45	50	56	60	65	70	74	80	85	90	94	98	100	110	120	
Acodus inornatus				1																			6
Acontiodus? curvus													1										1
Ambalodus elegans																							2
A. triangularis	2																						2
Belodina compressa		1		4		5		3	2	5		8	7	1			1			11		14	104
B. diminutiva																							3
B. inclinata																							1
Cordylodus delicatus									2		1												10
C. flexuosus									1														8
Dichognathus spp.	40	7	5	15	4	8	7	19	45	100	4	35	210	190	10	100	45			140	65	210	1910
Distacodus procerus													2									1	4
Drepanodus suberectus					1					1			3							4		4	27
D. spp.	7			1	1		1	8	13	14	6	25	25	20		15	6	2		36	50	25	418
Eobelodina fornicala		2										2								1		2	23
Oistodus abundans	25	3	6	9	1	5	4	16	25	40	3	23	40	45	4	55	19			120	45	150	1096
O. inclinatus	1	1	1		2	2	1	3	5	2	1	1	1	1		4	1	1		10	5	5	73
O. pseudoabundans		1			2							2										3	10
O. venustus	1						1																5
Ozarkodina cf. *O. tenuis*									1			?1											11
Panderodus spp.	8	12	2	8	6	4	6	1	1	10		9	22	3	3	6	2			50	17	43	377
Periodon aculeatus	1																						1
Phragmodus undatus	45	10	10	35	7	12	30	25	30	240	21	40	520	440	25	180	65			220	100	510	3600
Polyplacognathus bilobata											3		6	7		13	7	7		25	11	24	147
P. ramosa											5	8	8	14	1	30	10	22		45	30	60	345
Prioniodina robusta																							1
Trichonodella barbara									1														4
T. exacta																							1
T. recurva									1														1
T.? tricurva												1								1	1		3
Zygognathus deformis																							3
"Fibrous"																							30
Totals	130	37	24	73	24	36	50	75	127	412	44	155	845	721	43	403	156	32		663	324	1051 (5425)	8227

TABLE 4. Conodont distribution, part 1. Wilderness and early Barneveld: Ingham Mills; City Brook; Martinsburg, Roaring Brook.







STRATIGRAPHIC SECTION AND CORRELATION CHART OF LOCKPORT FORMATION IN NEW YORK STATE

557.73 N7N35

TABLE 9	DEER RIVER																														GULF STREAM					TOTAL
	DENMARK									COBOURG																					COBOURG					
										HALLOWELL																253	HILLIER					HILLIER					
SAMPLES →	2	10	20	30	40	50	60	70	80	86	99	109	119	130	140	148	158	168	179	187	196	208	216	228	240	250	255	266	268	270	284	1	10	20	25	35	
Acodus inornatus															1										1			1						1		2	6
A. aff. *A. unicostatus*																							2	2	1	1	1	1		4							12
Acontiodus falcatus?																							1														1
A.? *curvus*								1																													1
Ambalodus elegans								1											1			1													3		6
A. pulcher															1							1	?1														3
A. triangularis	11	2			1			1		2		1			1	1	1	2	3	2					1	1	1	19	30	23	20	4	40	65	25	100	357
Amorphognathus ordovicica	5		1		1				?1										1	2								7	13	8	15	2	17	30	24	35	162
Belodina compressa													3			7		3	6	5	3		4	1	11	2	9	13	12	18	12						109
B. dispansa																	1			1			1														3
B. inclinata																									?1												1
Coelocerodontus tetragonius																				1										1							2
C. trigonius		1					1				5								1			1					1			1							11
Cordylodus delicatus	7	3						10		9	21	9	11	11	18	50	11	50	35	25	16	3	1		11		4	5	7	9	7	1	7	1	8		350
C. flexuosus	2	8					1	2		5	30	15	13	15	21	20	10	40	13	11	6	2	1		5	1	2	3		3	3	3	8	5	10	1	259
Dichognathus spp.	90	230	45	6	65	7	440	35	2	100	420	14	22	60	19	90	7	40	140	110	35	16	35	24		4	2	35	7	40	3	1			6	3	2153
Distacodus falcatus	1	3			1					2	2					1		2	2	6	1				1	1			1		1						25
D. procerus		1																				1					1	1								1	5
D.? *trigonius*								1														2			1		1			1							6
Drepanodus suberectus		2	2	1	2	1	4	2		2	6		1	3	2	2	2	2	2	2	2	1			1		1										43
D. spp.	19	21	5	2	14	6	50	30	3	40	100	25	22	35	35	50	7	140	40	40	22	10	6	9	21	4	13	11	10	17	11	1	6	11	3	35	874
Eobelodina fornicala																		1	1	1			2	1	6	2	4	3	1	3	4						29
Falodus prodentatus		3	1	1	5		24	2			8	1				1				3	6	1	2	1	2			1	2	1	1	1		2			69
Goniodontus superbus					1																														1	6	8
Holodontus superbus	1																														1						2
Icriodella superba												2			8	2				4	3	35	9	8													71
Ligonodina tortilis			1				3																														4
Oistodus abundans	65	141	30	7	50	3	320	25	2	110	300	11	6	50	20	50	14	85	110	95	30	11	35	18	1	2	4	15	10	24	13					5	1662
O. inclinatus	2		2	1	4	2	16	4		13	9	3	1	1	8	6	3	11	5	8	5	3		1	5	4	4		1	3	5		1			1	132
O. venustus																									3	2	4	8		3	1			1	4		26
Ozarkodina cf. *O. tenuis*		2	1					4		13	19	19	30	17	22	21	6	65	37	30	13	6	3		11		10	2	7	10	12	3	3	5	13		384
Paltodus dissimilaris										1																											1
Panderodus spp.	6	15	3	8	22	11	150	150	10	340	280	140	35	150	240	70	30	24	110	220	110	65	55	35	140	40	190	180	160	140	380	50	60	45	35	6	3705
Periodon aculeatus					3		35	1			13	1					1			5						1					1	1					62
Phragmodus undatus	150	380	90	8	110	9	890	55	3	150	830	40	55	110	45	175	18	85	230	160	50	18	45	17		5	5	60	12	35	5			1	5	5	3856
Prioniodina macrodentata		1					6	1			9												1			1		1					2				22
P. pulcherrima	1	1									14	9	13	6	15	19	4	22	16	6	4	4	1	1	5	1	6		2	5	7		3	1	4		170
Rhipidognathus paucidentata																			3																		3
Rhynchognathodus divaricatus		3	1		1							1		3	8	1				1		2	3	3													27
R. typicus			2											3	4	1		1			2		2														15
Rosagnathus delicata	3	1												1	3	1		1	3	1		1	1		3			11	18	10	8	3	9	24	7	40	149
Sagittodontus dentatus		1														2		1		1	1		2	2													10
S. robustus														1	2				1	1		7	3	2	1												18
Scolopodus insculptus								1														2										4			1	1	9
Trichonodella exacta	2	1						1		3	11	5	4	5	5	8	2	9	12	11	3	1						1	1	1	4				4		94
T. flexa		3						1		2	9	2	5	4	12	9	3	16	5	6	5	2		1	1	1	2		1	1	2	1	1		2		97
Zygognathus deformis	1	2	1	1				2		1	8	9	6	8	15	15	1	12	11	11	6	1			2	1	2	2	2	5	4				3		132
Totals	366	825	185	35	280	39	1940	330	21	793	2094	307	227	483	505	602	121	612	788	769	323	197	216	126	235	74	267	380	297	366	520	75	157	192	158	241	15146
																															(14323)					(823)	

TABLE 9. Conodont distribution, part 6. Barneveld: Deer River; Gulf Stream.

TABLE 8

SAMPLES →	CITY BROOK									
	SHOREHAM	DENMARK								
		69								
SAMPLES →	65	75	85	95	104	105	120	125	130	135
Acodus inornatus	1	1				2				
A. numaltipes		1								
A. similaris						4				
A. aff. A. unicostatus										
Acontiodus? curvus										
Ambalodus elegans	5									1
A. pulcher	2									
A. triangularis	1	7	1			30	1			2
Amorphognathus ordovicica		6	1			20				
A. tvaerensis										
Belodina compressa										
B. inclinata										
Coelocerodontus tetragonius										
C. trigonius						7				1
Cordylodus delicatus										
C. flexuosus										
Dichognathus spp.	1	9	2	2	2	75	2	1		2
Distacodus falcatus		1								
D. procerus			1		1	3				
D.? trigonius										
Drepanodus suberectus	1	1				11				
D. spp.	11	40	4			160	1			
Eobelodina fornicala										
Falodus prodentatus	19	2				45	7			
Goniodontus superbus						?1				
Holodontus superbus						2				
Icriodella superba										
Ligonodina tortilis	1	1				5	2			
Oistodus abundans	1	6	3	1		30	3			3
O. inclinatus	2	6	1			25	1			
O. venustus		1				10				
Ozarkodina cf. O. tenuis										
Panderodus spp.		2				11	3			
Periodon aculeatus	7	6				30	5			
Phragmodus undatus	4	4	11	4	5	110	10	1	1	3
Prioniodina macrodentata						22				
P. pulcherrima										
Polyplacognathus bilobata	29									
P. ramosa	60									
Rhynchognathodus divaricatus										
R. typicus										
Rosagnathus delicata	2	4				50				1
Sagittodontus dentatus										
S. robustus										
Scolopodus insculptus		1				4				
Trichonodella exacta										
T. flexa										
Zygognathus deformis										
Totals	147	99	24	7	8	657	35	2	1	13
										(993)

SAMPLES →	MARTINSBURG, ROARING BROOK																	
	SHOREHAM				DENMARK													
				169														
SAMPLES →	130	140	150	160	170	180	190	195	200	211	220	230	240	250	260	270	280	288
Acodus inornatus				1			1			1	2			1				
A. numaltipes															2		1	
A. similaris																		
A. aff. A. unicostatus															1			
Acontiodus? curvus	1					1										1		
Ambalodus elegans	13	1																
A. pulcher	4	1	3															
A. triangularis		2	24	15	12	8	1	1	1	1	5	1		1			1	3
Amorphognathus ordovicica			5	4	9	1	1				2					1		1
A. tvaerensis					1				1									
Belodina compressa																		
B. inclinata																		
Coelocerodontus tetragonius										1								
C. trigonius						1	1		1	3	2			1		1		
Cordylodus delicatus										?1			2			2	5	6
C. flexuosus															1	2	6	6
Dichognathus spp.	22	6	510	130	25	270	400	30	35	190	80	2	100	25	30	170	22	14
Distacodus falcatus							2		1	3	1		1		7	1	1	2
D. procerus							1											
D.? trigonius															1			
Drepanodus suberectus					1				2	2			1					
D. spp.	13	7	60	13	17	18	24	2	12	24	6	5	17	6	30	45	55	22
Eobelodina fornicala																		
Falodus prodentatus	2		3			2	2			4	8				12	22	1	2
Goniodontus superbus																		
Holodontus superbus			8	2		3												
Icriodella superba		11	14	4														
Ligonodina tortilis																		
Oistodus abundans	5	1	430	40	22	100	240	8	24	80	25	2	60	13	90	120	25	25
O. inclinatus	3	2	5		1	1	3		2	2	1	1	1		11	2	4	6
O. venustus		1		2	1	3				3								
Ozarkodina cf. O. tenuis															1	4	8	3
Panderodus spp.	1		3	1	1	2	25	3	3	35	12	15	23	13	130	135	60	80
Periodon aculeatus					1					6	1					14		
Phragmodus undatus	36	8	800	310	40	680	890	55	50	360	130	2	210	40	50	260	25	35
Prioniodina macrodentata						1									1	4		
P. pulcherrima																5	4	
Polyplacognathus bilobata																		
P. ramosa																		
Rhynchognathodus divaricatus		3	23	1										1				
R. typicus		1	13															
Rosagnathus delicata	5		60	11	15	12				1	5							
Sagittodontus dentatus		1	11															
S. robustus		3	17	1														
Scolopodus insculptus															5		1	1
Trichonodella exacta																1		1
T. flexa										1					1	1	3	
Zygognathus deformis																	2	1
Totals	105	48	1989	535	146	1103	1591	99	132	718	280	28	415	101	373	791	224	208
																		(8885)

SAMPLES →	MARTINSBURG, ATWATER CREEK							TOTAL
	COBOURG							
	HALLOWELL					HILLIER		
					45			
SAMPLES →	1	10	20	30	40	50	61	
Acodus inornatus								10
A. numaltipes								4
A. similaris								4
A. aff. A. unicostatus								1
Acontiodus? curvus								3
Ambalodus elegans								20
A. pulcher								10
A. triangularis			2	12	8	3	5	148
Amorphognathus ordovicica			1	7	15	2	3	79
A. tvaerensis								2
Belodina compressa			4	4	1			9
B. inclinata		2		2				4
Coelocerodontus tetragonius					1			2
C. trigonius								18
Cordylodus delicatus			2	1	1	2	1	23
C. flexuosus			5	1		1		22
Dichognathus spp.	14		5	1	2			2179
Distacodus falcatus			3					23
D. procerus								6
D.? trigonius	1							2
Drepanodus suberectus								19
D. spp.	13	8	5	6	5	4		633
Eobelodina fornicala				1	1			2
Falodus prodentatus	1			1				133
Goniodontus superbus								1
Holodontus superbus								15
Icriodella superba	10	5						44
Ligonodina tortilis								9
Oistodus abundans	20		12	4				1393
O. inclinatus	1	3	3	1	1	1		90
O. venustus	2		1					24
Ozarkodina cf. O. tenuis	1	1	12	2	3	1		36
Panderodus spp.	60	35	90	25	30	30	10	838
Periodon aculeatus		1			1			72
Phragmodus undatus	30	2	14	2	2		1	4184
Prioniodina macrodentata								28
P. pulcherrima	2		5	1	2		1	20
Polyplacognathus bilobata								29
P. ramosa			?1					61
Rhynchognathodus divaricatus	1	1						30
R. typicus	2	1						17
Rosagnathus delicata	2		1	2	1	1		173
Sagittodontus dentatus								12
S. robustus	5	1						27
Scolopodus insculptus						1		13
Trichonodella exacta			1		2		1	6
T. flexa					2			8
Zygognathus deformis			2		1			6
Totals	165	60	169	73	79	46	22	10492
							(614)	

TABLE 8. Conodont distribution, part 5. Barneveld: City Brook; Martinsburg, Roaring Brook; Martinsburg, Atwater Creek.

TABLE 7	TRENTON FALLS																																										TOTAL
	DENMARK																					COBURG HALLOWELL																					
																						120																					
SAMPLES⟶	1	2	4	5	8	10	16	23	30	35	42	48	57	63	69	74	80	88.5	98	108	112	119	126	135	141	147	153	159	168	177	186	195	201	210	216	225	231	240	246	252	259	261	
Acodus inornatus												2	1																														3
A. numaltipes																									2											1							3
A. aff. A. unicostatus																								7							1												8
Acontiodus? curvus												1													1							1											3
Ambalodus elegans	1										1															1																?2	5
A. pulcher																		1														2											3
A. triangularis		2	3	5		1			1		3	5	1					1												1				6	3	5	6						43
Amorphognathus ordovicica	1	1	1	1							1		3			1	1		1									2		1				1	2	1	1						19
Coelocerodontus tetragonius											1																1					1	4							1			8
C. trigonius													6	1			4	2	5					3				3	3	1		1	7		1				1	2			40
Cordylodus delicatus													1											4							3									2			10
C. flexuosus																								4							2			1		2			?1				10
Dichognathus spp.	20	40	17	13		11	9	1	50	80	40	45	65	15	30	60	60		23	35	100	20	17	140	80	75	21	50	17	22	90	75	5	13	40	8	13	8	14	45		1	1468
Distacodus falcatus										1																										1					1		3
D. procerus			1				1			1			1			1	3		2												2												12
D.? trigonius																							1	3																			4
Drepanodus suberectus	3								1												2		1	5			2					1			1	1	1	2	1	5	1		27
D. spp.	3	5	9	9		3	8		6	11	12	6	11	5	3	7	8		3	3	16			28	7	4	7	8	16	6	12	5	8	19	24	3	12	13	5	27	4	1	337
Falodus prodentatus	1	1					1		10	6	2	3	1					2			8		24	81	27	19	3	5	12	3	1	2				1			1	4		1	219
Goniodontus superbus			1																																								1
Icriodella superba	2																		1																								3
Ligonodina tortilis																					1		1	2	7	2	1		1	1									1				17
Oistodus abundans	11	9	12	3		4	6		17	25	15	25	25	9	6	14	35		14	15	65	4		95	30	40	6	22	11	15	25	30	8	9	22	8	5	5	13	24	2	2	686
O. inclinatus	1		2			1	1			2	1	1				1			1		2		2	6	2		1		3	2	3	1	6	5	9		3	3	1	7	2	1	70
O. venustus		2										2	1				2							1																			8
Ozarkodina cf. O. tenuis																								1				1			1			2	4	1		1		5	1		17
Paltodus dissimilaris																														1						2			1				4
Panderodus spp.										2		2	3			10	3		3	2	7	1		106	7	2	7	7	6	3	31	2	1	13	1	4	4	11	4	17			259
Periodon aculeatus	1								23	10	3	1						1			4		16	58	28	10	11	2	7	3	2	1								2			183
Phragmodus undatus	40	40	25	6	2	7	12	5	90	110	80	100	95	35	40	130	165		90	40	200	40	30	260	95	160	45	75	45	40	160	130	22	16	40	20	16	8	30	75	3	4	2626
Prioniodina macrodentata							1		6	2	1		1								1		9	19	8	5	3	3	3	5	1									1			69
P. pulcherrima																								5							1									1			7
Rhynchognathodus divaricatus		1								1																																	2
Rosagnathus delicata			1	1					1	2	4	1				3	4			1						2						1		2			2						25
Sagittodontus robustus		1																																									1
Scolopodus insculptus																1		1			1				2								1	1	1	1		3	3	3	1		19
Trichonodella exacta																																							1	1			2
T. flexa																								1							1							1		2			5
Zygognathus deformis																								3																2			5
Totals	84	102	72	38	2	27	39	6	205	253	164	194	215	65	79	228	285	8	143	96	407	65	101	832	296	320	108	178	124	104	336	253	62	88	148	59	63	55	77	226	15	12	6236

TABLE 7. Conodont distribution, part 4. Barneveld: Trenton Falls.

TABLE 6	HULL CEMENT QUARRY						KIRKFIELD QUARRY								COBOCONCK QUARRY							LOWVILLE							
	KIRKFIELD(?)						BOBCAYGEON						VERULAM		GULL RIVER					BOBCAYGEON		PAMELIA		LOWVILLE			CHAUMONT	ROCKLAND	
							MIDDLE MEMBER		UPPER MEMBER											LOWER MEMBER									
									4				38							20				30			64	77	
SAMPLES →	10	61	98	107	113	116	1	2	7	18	24	29	40	45	1	6	8	13	18	21	27	1	25.5	31.5	45	47.5	71	83	TOTAL
Acodus inornatus	1						2	7	13	3	3	9	11	3															52
Ambalodus pulcher		?1																											1
Belodina compressa	2	30	5				25	25	25	18	25	100	60	55			?1	12		5						1		1	390
B. diminutiva								2		1		1						3	1	1	1							1	11
B. dispansa		1								1		1	6	1				1											11
B. inclinata							2				1	1						2						3					9
B. ornata							1		1						1			1		3	2			1					10
Bryantodina abrupta			4					3	1	1	16	14	2	3															44
Cordylodus delicatus		8	35	2		3	3	21	3	3	6	14	1	2		?1			1	1				?1			?2		107
C. flexuosus											2																		2
C. n. sp.			6								1	1		1															9
Dichognathus spp.	11	170	15			2	1	35	30	45	30	140	460	230	?1				?1	?1									1172
Distacodus procerus		1					1	4	6	3		5	4	1															25
D.? trigonius												1																	1
Drepanodus suberectus	2	5						2			2	5	6	5				2											29
Drepanodus spp.	4	40	14	3	1		18	16	30	23	30	140	50	55				6	2	2	1			4				2	441
Eobelodina fornicala		10	1				5	4	6	2	5	14	19	10							1								77
Oistodus abundans	3	70	17	2			4	6	23	5	30	90	220	140															610
O. inclinatus	4	8	2	?1			6	5	3		6	7	8	13				1		1									65
O. pseudoabundans		?1	1				6	5	8	12	3	17	40	2							1								96
Ozarkodina cf. O. tenuis		2	8		?1	4	4	14	12		4	11						?5		2				?1	?1				69
Panderodus spp.	5	30	45			4	30	24	50	40	30	140	220	160	11	2	1	11	4	14	8	?1		2		1	1	7	841
Phragmodus undatus	20	170	25	1	3	7	4	65	60	100	45	360	800	450					?1										2111
P. cognitus?							3	1	1				6																11
Polyplacognathus bilobata	10	5					2	2	7	4	11	16	8	16															81
P. ramosa	20	18	3	2			3	6	8	13	19	55	18	22															187
Prioniodina robusta		5	15				4	16	2	2	4	4	1	2															55
Rhipidognathus paucidentata											4	12	5	1															22
Trichonodella barbara		2	4			3	1	8	1		2	3		1													1		26
T. flexa											2	7		1															10
T. recurva		9	10	2		2	1	5	1		4	5			1									1	?1		2		44
T.? tricurva											2	8	4																14
Zygognathus deformis		4	12	3		1	4	5	2	5	1	10			1			1		3				1					53
"Fibrous"			1	1					2			1		2	3	10		2		6	4	2	2	16	4	7	4	3	70
Totals	82	590	223	17	5	26	130	281	295	281	288	1192	1949	1176	18	13	2	47	10	39	18	3	2	30	6	9	10	14	6756
						(943)								(5592)							(147)							(74)	

TABLE 6. Conodont distribution, part 3. Wilderness and early Barneveld: Hull Cement Quarry; Kirkfield Quarry; Lowville.

TABLE 5	KINGS FALLS, DEER RIVER													DEXTER QUARRY										ROCKLAND QUARRY									TOTAL
	ROCKLAND			KIRKFIELD					SHOREHAM					CHAUMONT	ROCKLAND							KIRKFIELD		CHAUMONT	ROCKLAND								
				15					115						5							63			1								
SAMPLES→	1	5	10	22	40	60	80	100	110	120	130	140	148	3	6	10	14	43	48	54	59	64	70	0.5	3	9	18	24	33	40.5	46	50	
Acodus inornatus				2					2	2		1							2	1												1	11
A. aff. A. unicostatus																																1	1
Ambalodus elegans												1																					1
A. triangularis																1																	1
Amorphognathus ordovicica																?1									1								2
Belodina compressa	1	2	3	30	1	20	7	17	7	2	3	8		5	11	42			5		1	2	2	4		4	2	1	1	2	10	9	202
B. diminutiva																										1					1		2
B. inclinata																															1	1	2
Cordylodus delicatus						6	3									1					2			2									14
C. flexuosus				1												3				1				1						1	2		9
Dichognathus spp.	22	13	18	75	21	100	90	120	160	130	95	420	14	24		790		13	30	16	35	2	10	3	17		7	2		1	11	1	2240
Distacodus procerus							1		3									1															5
Drepanodus suberectus	1			8		1	1	1	6	2	7	3		1		6									1	1			1		2		42
D. spp.	2	3	11	20	7	18	12	12	16	30	85	45	12	8	4	155	1	1	20	11	13			10	7	1	7	3	4		4	8	530
Eobelodina fornicala			1	6		5	4	4	2	1		4				4			4					1							1		37
Falodus prodentatus													1																				1
Icriodella superba																8									1								9
Ligonodina tortilis													1																				1
Oistodus abundans	12	15	11	55	10	90	40	70	55	45	65	400	22	4		320	2	5	30	15	35		1	4	35	1	3		1	3	3		1352
O. inclinatus	4	2	4	9	1	5	2	3			13	10	3	?1		30	1		2	1		1	1	2		1			1		2	1	100
O. pseudoabundans		1		5			2								1	6			1										1				17
O. venustus			1																													1	2
Ozarkodina cf. O. tenuis		2	2	1	1	1	2	2								2					4			1							2	1	21
Panderodus spp.	2	3	25	85	3	5	23	4	30	40	17	45	2	11	10	35	2	3	21	4	4	1	3	17	30	2		4	7	7	21	31	497
Periodon aculeatus													1																				1
Phragmodus undatus	20	22	35	180	23	110	95	170	260	190	100	780	37	13		510	4	30	45	24	35	7	4	3	24	4	10		3	4	12	5	2759
Polyplacognathus bilobata						1		6	12	18	50	16	9																				112
P. ramosa						3		10	30	20	115	75	40																				293
Prioniodina robusta							2																1									1	4
Rhynchognathodus divaricatus																3																	3
Rosagnathus delicata												1	1			1																	3
Sagittodontus dentatus																1																	1
S. robustus																2																	2
Trichonodella barbara				1		1	2								1																		5
T. recurva					1	1								1						1	1												5
T.? tricurva								1			1	1																					3
Zygognathus deformis		1		1	1	4																		1								1	9
"Fibrous"																						4	2	3			1						10
Totals	64	64	111	479	69	371	286	420	583	480	551	1810	143	68	27	1922	10	52	160	74	130	17	24	52	116	15	30	10	19	18	72	62	8309
													(5431)										(2484)									(394)	

TABLE 5. Conodont distribution, part 2. Wilderness and early Barneveld: King Falls, Deer River; Dexter Quarry; Rockland Quarry.

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